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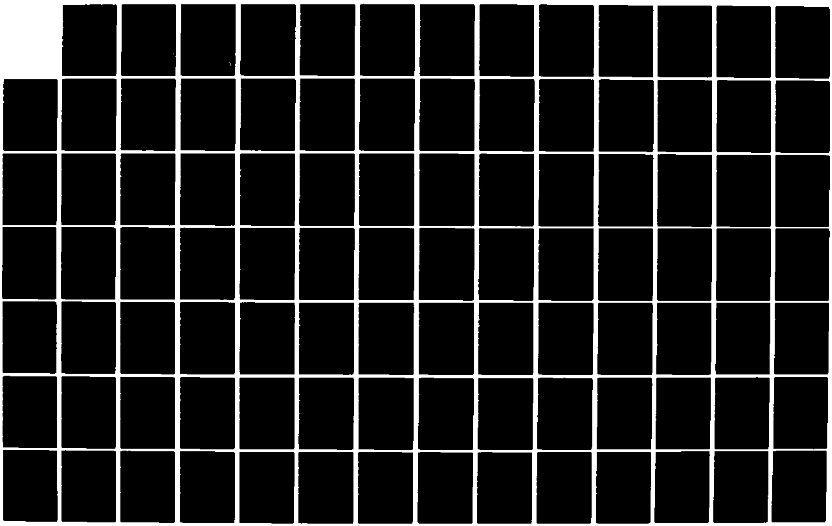

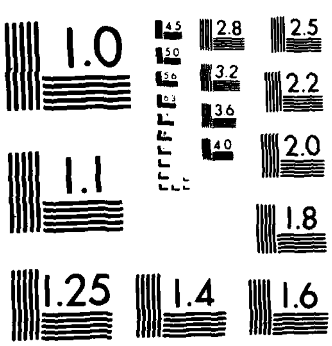

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ALTERNATIVES FOR EXTENDING THE EUROPEAN DISTRIBUTION SYSTEM'S LOG C3I SUBSYSTEM TO THE COLLOCATED OPERATING BASE LEVEL

THESIS

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Captain, USAF

AFIT/GLM/LSM/84D-1

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THESIS

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Logistics Management

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Preface

The primarily peacetime command, control, and communications system recently contracted for by Air Force Logistics Command's European Distribution System Program Office is only the first step in the realization of a truly theater-wide redistribution capability. Although inclusion of all wartime locations into the EDS C^3 network is the ultimate goal, the actual mechanics of accomplishing this extension had not been addressed. It is towards that end that I hope this study has contributed.

Subsequent to completion of this research, the "Intelligence" portion of the EDS C^3I subsystem title was dropped in order to more accurately reflect the system's function. This change is not reflected in the text but the reader should be aware of its existance.

I am indebted to several people for their help with this project. First, I wish to thank my thesis advisor, Mr. Dennis Campbell, for allowing me the freedom to pursue this topic in the manner which I thought best and for his assistance and counseling when the research effort took an occasional odd turn. Also, I extend my gratitude to the people in the European Distribution System Program Office who provided much of this study's background. Finally, I wish to thank my wife Kathleen and our children for their patience and support during this effort.

Kevin F. Donovan

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Abstract

This study analyzed the communications and Automated Data Processing Equipment (ADPE) options available to extend the original configuration of the new European Distribution System's (EDS) Command, Control, Communications, and Intelligence (C^3I) subsystem from Europe's Main Operating Base (MOB) level to the Collocated Operating Base (COB) level. This extension is essential in order to achieve the payoffs predicted by RAND Corporation Study Number R-2860-AF upon which EDS development was justified.

The basic approach taken to conduct this analysis was to first determine acceptable configurations for the extended system. With these in mind, C^3 systems that are fielded or soon to be implemented in the European theater were examined f-- possible integration into EDS. Additionally, emerging and other possible C^3 technologies were identified for further analysis. These preceding steps provided a list of C^3 alternatives for evaluation under a technique known as the Brown-Gibson approach which rank-orders the options using both subjective and objective (cost) criteria.

The results of this analysis indicated that the ADPE segment of the COB EDS system should be integrated with other ADPE systems destined for use at the COB and that the Combat Supply System, currently under development at the Air Force Data Systems Design Center, was the preferred choice. From a communications standpoint, analysis showed that several

alternatives should be incorporated including existing Air Force and North Atlantic Treaty Organization (NATO) circuitry, dial-up entry into the Movement Information Network (MINET), and perhaps satellite solutions. Sensitivity analysis demonstrated that these results were valid over a wide range of cost considerations and evaluation treatments.

ALTERNATIVES FOR EXTENDING THE EUROPEAN DISTRIBUTION SYSTEM'S LOG C3I SUBSYSTEM TO THE COLLOCATED OPERATING BASE LEVEL

I. Introduction

General Issue

A recent Rand Study (#R-2860-AF) concluded that because United States Air Forces in Europe (USAFE) lacks an effective critical spare parts distribution system, over 300 fighter aircraft will be grounded each day of a European war, resulting in the loss of over 800 daily sorties. Given the fact that the North Atlantic Treaty Organization's (NATO) tactical air power is already quantitatively inferior to the Warsaw Pact's, getting the most out of our existing assets is imperative. The need to sustain our forces with an effective and efficient logistics support system becomes paramount in the face of this quantitative inferiority. The difficulties of supplying combat units with critical spare parts under dynamic battlefield conditions present major challenges to commanders in the field. A program titled the European Distribution System (EDS) seeks to redress this problem by establishing a spare parts distribution network based on three major sub-systems: dedicated aircraft, in-theater warehouses, and an automated command, control, communications and intelligence (C^3I) system.

Specific Problem

Initially, the EDS program plans to install and operate

C^3I microcomputers only at USAFE Main Operating Bases (MOB), airfields where USAF resources operate in peacetime. These micros will be tied electronically to: 1) that base's supply computer to determine on-base availability of needed spares, 2) other MOB's for sharing of resource availability information, and 3) the Logistics Readiness Center for management control of this newly created "pool" of assets. However, many tactical units will be deploying to over 70 Collocated Operating Bases (COB -- non-US military facilities not occupied by USAF units during peacetime). Because the EDS C^3I subsystem does not extend down to this level, the tremendous amount of critical spare parts located at these COB's will not become part of the theater pool, seriously limiting the EDS goal of providing a responsive spare parts redistribution system through centralized management control of <u>all</u> theater assets. The specific problem, then, is to identify the best alternative(s) for extending this EDS C^3I subsystem to the COB level, thereby integrating their assets into a true theater pool of critical spare parts.

Background

General. The Arab-Israeli War of 1973 demonstrated that the high attrition in a force's weapons systems must be offset by an efficient, effective resupply system to provide not only replacement of equipment lost but also ensure that surviving assets can continue to be used. Particularly important is the ability to distribute critical spare parts needed to keep aircraft flying or an essential C^3 network operating. The U.S. Air Force does not believe an effective distribution system exists in Europe today to accomplish this task in a NATO war (60:1). The paramount importance of establishing such a system is reflected in the words of Defense Secretary Weinberger: "No matter how large our forces or how modern our military equipment . . . if they cannot be sustained once engaged, we have no real combat capability." (59:31)

<u>The Problem</u>. Presently, most USAFE bases rely extensively on the Continental United States' (CONUS)-based system of depot support for essential spares, such as aircraft engines and radar parts. If receipt of an item cannot wait for delivery from the CONUS, supply managers telephone nearby bases that potentially stock the part, determine if that base is willing to release it, and if so, arrange transportation. The choice of transportation mode usually has little to do with normal managerial considerations such as cost, reliability, and to a certain degree, speed and damageability; the options are usually limited to what is available. Trucks are dispatched if feasible, opportune airlift is used, even tactical fighters are diverted after completing training missions. Intermodal deliveries are not uncommon in that the user and the source might often meet at a convenient location between the two (21:1).

The present "informal" (21:1) system is inefficient at best. Time delays and unavailability of scarce airlift resources make shipping critical spare parts from the CONUS unacceptable during war. Lack of a centralized management structure with near real-time information on parts in-theater could lead to situations where local commanders "protect" their assets, whether needed now or not, in anticipation of future use. Communications circuits and equipment needed to collect information, order parts, and arrange delivery are saturated and vulnerable. Potential for human error in order taking, processing, status keeping, and shipping arrangements abound. Finally, the lack of responsive, flexible transportation creates operational and maintenance problems up and down the chain.

The U.S. Air Force, noting the problems above, is convinced that the critical spares will not be at the right place at the right time during war because a dedicated physical distribution system does not exist. A variety of evidence is cited to back up this claim. During World War II, C-47 aircraft were pulled off their primary mission of moving troops and equipment in order to redistribute spare parts. The lack of a dedicated spares distribution system also hampered efforts in Korea and Vietnam. Again, the importance of sustaining combat forces during these conflicts resulted in the reallocation of scarce in-theater airlift assets. Simulation models already project theater airlift shortfalls in the event of a modern NATO conflict. Current studies have also shown that redistributing critical spares in peacetime returns about 40% of grounded fighters to operational status and that this redistribution takes an average of three days under the present system (18:5). Obviously, wartime will push this latter figure up enormously.

The Consequences. Rand Study number R-2860-AF (21:1) concluded that the lack of time and place utility for critical spare parts could result in up to 304 fighter aircraft grounded each day. This translates into about 800 fighter sorties lost per day at wartime surge rates (60:70). This startling figure is made worse with the knowledge that this analysis assumed all required spares needed today were on hand now, a situation that will not occur until FY85 at the earliest (18:6). The daily grounding of 304 fighters represents a $1.5 billion dollar investment and 47% of the available peacetime fighter force (18:6). Given the fact that NATO aircraft will be heavily outnumbered, the loss of this much capability is unacceptable to the U.S. Air Force. During peacetime, this loss results in operating inefficiencies -- in war, it could translate into combat losses because of the holes it creates in an already overstretched defense.

The Solution: European Distribution System (EDS). The Air Force answer to the redistribution problem is EDS. The systems approach is evident in the design of the program. Specifically, EDS is composed of three closely related subprograms: 1) EDS airlift (EDSA), 2) EDS warehouses and 3) Command, Control and Communications (C^3). The problem of wartime redistribution cannot be relieved unless all three elements are present and operate effectively.

Airlift. Procurement of additional commercially available, low cost aircraft represents the major portion of the transportation subsystem. Airlift is deemed necessary due to the nature of the goods being shipped -- speed is essential in order to get valuable aircraft flying again as soon as possible. In this case, the level of desired customer service justifies the trade-off of speed for cost.

In March of 1984, the Air Force selected the twin turboprop Sherpa, made by Short Brothers Ltd. of Northern Ireland, as its choice for the EDS aircraft. The contract calls for delivery of 18 aircraft at a cost of over $54 million to the Military Arilift Command's reactivated 10th Military Airlift Squadron based at Zweibrucken Air Base (AB) Germany.

Performance capabilities of the Sherpa include a 4200 lb payload, 157 knot airspeeed, and the ability to operate from airfields as short as 1500 feet. The aircraft is also capable of night and adverse weather operations. The first EDS aircraft are scheduled for delivery in the Fall of 1984 (1:38). Options exist for the eventual purchase of up to 48 more (60:70).

Initial cost-benefit projections for the EDS aircraft (and system as a whole) appear highly favorable. The FY83 allocations include $14.0 million for 2 aircraft and procurement of the C^3 system. FY84 calls for $61.4 million for 16 more aircraft and establishment of a warehousing system. The start-up costs, then, are estimated to be $75.4 (18:11).

This compares favorably with the $419 million cost of buying and operating more C-130's to handle the redistribution problem. Additionally, the Air Force estimates flying hour costs for the EDS aircraft at $500 as opposed to $1800 for a C-130, resulting in an annual cost savings of $41 million (18:3).

Warehousing. This segment of the EDS program calls for moving forward some of the critical spares needed for a war and positioning them in-theater. This has the effect of shortening the supply pipeline from an estimated 14 days to 1 day (9:), allowing logistics managers to be more responsive to their flying customers. Although many critical parts are deployed with a unit as part of their Wartime Readiness Spares Kits/Base Level Self-Sufficiency Spares (WRSK/BLSS), these kits of spares were not designed to sustain a unit through a prolonged conflict. Additionally, these resources are subject to uneven usage and colateral damage. These factors require a secondary source within close proximity.

Present plans call for establishing warehouse facilities at the Royal Air Force (RAF) base at Kemble in the United Kingdom to serve the Northern Sector of Europe, Zweibrucken AB in Germany acting as a system hub and also serving the central region, and either Torrejon AB in Spain or a location in Italy to serve the southern flank (60:70). As a result of recent site survey visits, managers within the EDS System Program Office (SPO) identified a facility in Belgium which they are considering as a replacement for Zweibrucken, or as possibly an additional site (9:). Because the EDS program does not include funds for construction of new buildings, all warehouse facilities will most likely be on a lease arrangement with the national owners (9:).

The EDS SPO is working closely with the CONUS Air Logistics Centers (ALC) to identify candidate parts for forward stockage. The process is nearing completion -- candidate lists are complete for items stocked by the Government Services Agency (GSA), Defense Logistics Agency (DLA), and the ALC's at Sacramento, Ogden, San Antonio, Warner-Robins, and Oklahoma City. Items to be stocked include equipment, consumables, and reparables with the obvious focus on War Readiness Material (WRM). Unlike the CONUS Air Logistics Centers, the European forward stockage facilities will have no repair capabilities (9:).

Log C^3I. The glue that will bind the EDS subsystem into a viable and hopefully, effective, management tool is the establishment of a command, control, communications and intelligence (C^3I) system that will allow logistics managers to track critical spares and reallocate them to the right units in a responsive manner. Before examining the EDS Log C^3I subsystem, it would be beneficial to understand the C^3 concept, particularly how it will be used in this study.

The acronym "C^3" is an evolutionary term. Many definitions have been offered but most tend to break it down into its components. Command and control (C^2) in a classical sense, can be defined as:

> The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel,equipment, communications, facilities, and procedures which are employed by a commander in planning, directing,co-ordination, and controlling forces and operations in the accomplishment of the mission (40:23).

Communications, then, is simply: "A method or means of conveying information of any kind from one person or place to another." (40:23) With these definitions, it is hard to draw boundaries around all the elements that constitute a C^3 system. Over the years, C^3 has become a generic term used to describe an automated and integrated military network designed to provide decision makers with near real-time information on a particular function and, in some cases, provide automatic direction to subordinate elements. Air defense C^3 systems are typical examples of this kind of description. As implied by the word "integrated," elements of a C^3 system must communicate with each other. Thus, communications is a means to an end; command and control is impossible in the modern battlefield without communications. Increasingly, the same is becoming true for computers -- hence the use in some circles of the term "C^4".

It is the description above that best characterizes the EDS approach to C^3. Although the EDS C^3 subsystem will not direct "forces" in a classical sense, it will direct and control "assets" (in this case, critical spare parts) by creating a network of inter-connected computers that share parts availability information and direct their movement between bases. More specifically, the purpose of the EDS C^3I subsystem is to "identify requirements, locate sources, and present information to help make decisions on the allocation of spares and other critical assets."(17:1)

Implied in the description above of a C^3 system is the presence of well established and consistently followed procedures for transferring information and directions. Beyond the hardware and software of the computers and the transmission medium to pass the information, end users must know what data to pass, when to pass it, and what to do with it when received. Usually it is the efficiency of the procedural aspect of a C^3 system that most greatly determines the effectiveness of the system as a whole. The following discussion describes the make-up of these three EDS C^3 components -- computer hardware and software, communications mediums, and an example of an EDS processing cycle to describe the procedural aspect. Any follow-on enhancement to the EDS Log C^3I system for COB units must be compatible with the system architecture described below.

Log-C^3I is essentially an automated system with the Logistics Readiness Center (LRC) at Ramstein AB, Germany, as its focus. Main Operating Bases (MOBs), the LRC, and the forward stockage warehouses are provided with Plexus Model P60 microcomputers provided by ITT's Federal Electric Corporation (53:). These micros are stand-alone, desktop size processors, yet still powerful enough to serve as the central processing unit for a minimum of 16 other on-base, remote terminals. Each EDS micro is connected to the Standard Base Supply System (SBSS) computer (if that base operates one) thereby permitting direct access to data bases concerning the on-base availability of a particular item. These micros represent the frontier of small computer technology -- 32 bit processors operating at a very fast 12 MHz clock speed with an on-line storage capacity of at least 300 Megabytes (17:6).

EDS micro systems come in three basic configurations. The typical configuration for the larger network elements, such as primary MOB's, the LRC, and theater warehouses, consists of the main processor with it's UNIX operating system and associated applications software, five video terminals, each with its own printer, and the requisite communications equipment for connectivity. Some main operating bases have supply systems that are slaved off other bases, a situation where the slaved MOB uses the larger base's SBSS computer for data storage and requisition processing. The configuration for these satellite elements includes one to three video terminals homed off the larger MOB microprocessor along with needed printers and communications gear. Finally, a transportable system, called PEWS (Portable EDS Workstation System), is also be available as backup to the main processors. The PEWS will most likely be Osborne Executive portable microprocessors with printers, modems, and uninterruptible power supplies/portable battery backup. Each network element has three PEWS' available for contingencies (45:5-7). Table 1 depicts tentative EDS C^3I operational locations.

TABLE 1

Tentative EDS C3I Operational Locations

<u>17TH AIR FORCE LOCATIONS AND SATELLITES(*)</u>

BITBURG AB, GE	SOESTERBERG AB, NL
HAHN AB, GE	ZWEIBRUCKEN AB, GE
SEMBACH AB, GE	RAMSTEIN AB, GE
RHEIN MAIN AB, GE	SPANGDAHLEM AB, GE
* LINDSEY AS, GE	

<u>3RD AIR FORCE LOCATIONS AND SATELLITES</u>

RAF ALCONBURY, UK	RAF BENTWATERS,UK
* RAF CHICKSANDS, UK	* SEMBACH AB, GE
RAF FAIRFORD, UK	* LIEPHEIM AB, GE
RAF LAKENHEATH, UK	* ALHORN AB, GE
RAF UPPER HEYFORD, UK	* NORVENICH AB, GE
* RAF GREENHAM COMMON, UK	RAF MILDENHALL, UK

<u>16TH AIR FORCE LOCATIONS AND SATELLITES</u>

AVIANO AB, IT	INCIRLIK CDI, TK
TORREJON AB, SP	* ANKARA AS, TK
* ZARAGOZA AB, SP	* DIYARBAKIR CDI, TK
* MORON AB, SP	* IZMIR AS, TK
SAN VITO AB, IT	HELLENIKON AB, GR
* COMISO AB, IT	* IRAKLION AB, GR

UK - UNITED KINGDOM; TK - TURKEY; GR - GREECE; IT - ITALY
SP - SPAIN; GE - WEST GERMANY; NL - NETHERLANDS

SOURCE: 45:13-16

The software designed for the EDS C^3I subsystem is designed to perform a variety of functions. Several on-line data bases will be created, the most important of which includes: 1) Stock Number User Directory (SNUD) listing: records in-theater users of a particular stock numbered item. Estimated storage requirements: 32 Megabytes. 2) MICAP (Mission Incapable - Parts) Requirements listing: a file containing those parts requisitions users declare as necessary for returning a weapons system to operational status. Estimated storage requirements: 1.7 Megabytes. 3) Freeze tables: a list of protected assets or units established and updated by the LRC. (More will be said about this important function later.) Estimated storage requirements: 100 Bytes. 4) Distance matrixes: determines closest activity available to satisfy a MICAP request. Estimated storage requirements: 26 Kilobytes. 5) SBSS Assets: A file record of all spares on-base. This file serves as a back-up in case of extended outages of the SBSS. Estimated storage requirements: 50 Megabytes. Total estimated data storage requirements for an EDS microprocessor would be 84 Megabytes with the biggest chunk going to the last back-up file, the SBSS Asset file. These data bases and connectivity to the local base computer and other EDS microprocessors will allow the system to perform its primary functions of generating inquiries into parts availability, identifying the source of the nearest resource, issuing shipping instructions, and tracking the fulfillment of its redistribution actions (45:1-4).

A major stumbling block in establishing an effective C^3 system in wartime is the extent to which that system relies on continuously available communications links. A primary goal in Warsaw Pact doctrine is disruption of our C^3 infrastructure -- a goal most easily attained through destruction and/or jamming of our vulnerable terrestial communications nodes. EDS planners recognize this threat and appropriately, have built redundancy into their communications planning which in turn enhances survivability. The EDS C^3 subsystem will employ both military and civilian data and voice communications systems including the Movements Information Network (MINET), Public Data Networks (PDN), Automatic Voice Network (AUTOVON), and Public Switched Networks (PSN).

MINET. EDS plans to use the new MINET network as its primary communications mode. MINET is a test project to exploit new packet switching technology introduced by the civilian Advanced Research Projects Agency Network (ARPANET). Packet switching and ARPANET technology is an extremely important advance in data communications and needs to be reviewed here.

Packet switching is a technique by which messages are broken down into smaller packets. The packets are each handled separately, routed along network links by high speed computers acting as switching centers or nodes. At each computer node, the packet is checked for errors, corrected, and sent along or reasssembled with other packets for message delivery to an addressee.

The advantages of packet switching are easily recognizable. Packet switching was specifically designed for computer communications and, as such, is very efficient in terms of circuit utilization and therefore, cost. Its high speed and error correcting capabilities deliver amazing performance projections: messages can be delivered across the United States in about 90 milliseconds, while the chance that an undetected error will slip by is in the 10^{-18} probability range (14:7). Additionally, the computers that comprise the switching nodes are small, relatively inexpensive, and reliable, allowing unattended operation in many cases. Thus, many such nodes can affordably be embedded in the network (14:3).

The advantages to the military in packet switching technology were clear enough to initiate the Automatic Digital Network (AUTODIN) II program which would have been a packet switching follow-on to the present AUTODIN system. Because of the importance of reducing communications costs and improving survivability, the AUTODIN II program was cancelled in 1981 in favor of an improved version, the Defense Data Network (DDN). Conceivably, DDN could eventually replace AUTODIN as the primary U.S. military data communications system.

MINET is the forerunner to and will eventually become the European component of DDN. It is being developed as a joint program whose purpose "is to improve the managing and tracking of cargo movements into and within the European theater."(2:1-5) The system will lease communications trunking circuitry from local Post Telephone and Telegraph (PTT) companies and connect them to Bolt Beranek and Newman Computer Corporation C/30 and C/70 computers, essentially the same as those used in the ARPANET (2:3-5). EDS locations will be homed off appropriate MINET node locations, again using 9600 bps leased circuits, as depicted in Table 2.

PDN. Each country in Europe has a public data network similar to Western Union in the United States. Most of these networks now use or plan to use packet switching technology as part of their commercial service to the public. PDN access by the EDS C^3I subsystem is considered an essential backup to MINET.

Unlike leasing full time circuitry which is very expensive, costs for PDN service would be limited to an initial hook-up fee and by-message costs thereafter. PDN also has the advantages of excellent redundancy, and therefore, survivability, because of the size and complexity of the established network. Since many locations are served by PDN, access to adjacent military facilities is also much more readily available.

One potential disadvantage to such a service is the lack of security. Although EDS C^3I will theoretically not pass any classified information, the lack of an encryption system may be detrimental in longterm follow-on development (46:v-ix).

TABLE 2

MINET Node Locations and EDS Subscribers

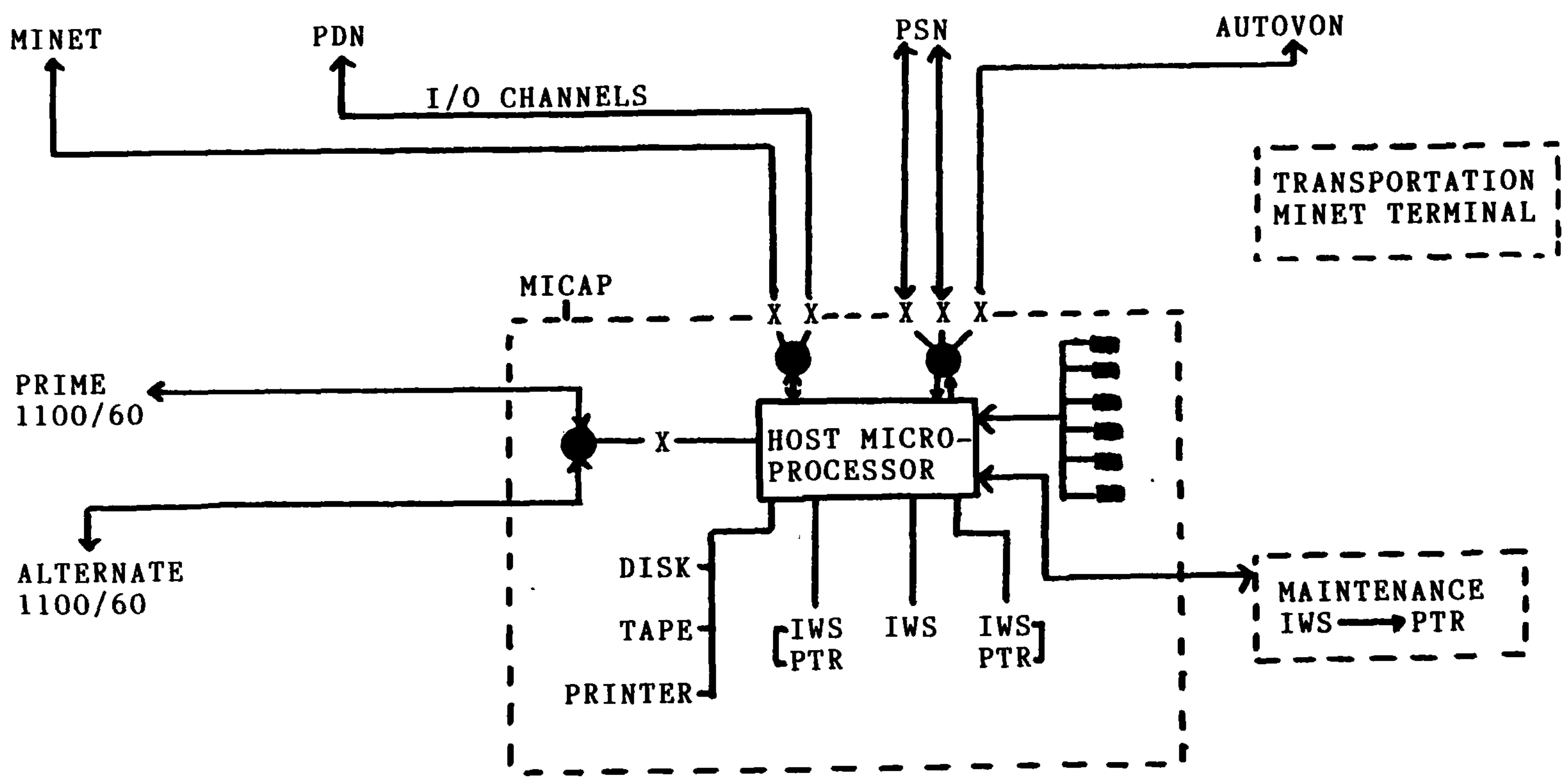
MINET NODE LOCATION	EDS SUBSCRIBER
RAMSTEIN AB, GE	RAMSTEIN AB, GE NORVENICH AB, GE RHEIN MAIN AB, GE SEMBACH AB, GE HAHN AB, GE SPANGDAHLEM AB, GE BITBURG AB, GE ZWEIBRUCKEN AB, GE
STUTTGART AB, GE	LIEPHEIM AB, GE
BREMERHAVEN, GE	ALHORN AB, GE
ROTTERDAM, NL	SOESTERBERG AB, NL
LONDON, UK	RAF ALCONBURY, UK RAF BENTWATERS, UK RAF CHICKSANDS, UK RAF FAIRFORD, UK RAF GREENHAM COMMON RAF KEMBLE, UK RAF LAKENHEATH, UK RAF MILDENHALL, UK RAF UPPER HEYFORD, UK
ROTA, SP	TORREJON AB, SP MORON AB, SP ZARAGOZA AB, SP
NAPLES, IT	AVIANO AB, IT COMISO AB, IT SAN VITO AB, IT
ATHENS, GR	HELLENIKON AB, GR IRAKLION AB, GR
ISTANBUL, TK	ANKARA CDI, TK DIYARBARKIR CDI, TK IZMIR CDI, TK INCIRLIK CDI, TK

SOURCE: 15:9-10

AUTOVON. The AUTOVON network is the DoD's primary voice communications network. Although generally too noisy for extended data transmissions, it could possibly be used for short duration messages. EDS microprocessors would use modems to convert outgoing digital signals into an acoustical form and vice versa for incoming traffic. EDS users would compete for AUTOVON access just as a voice user would. Additionally, AUTOVON is routed over relatively vulnerable Defense Communications System (DCS) facilities which include microwave towers, above ground switching facilities, and land landline systems. Availability, reliability, and survivability are therefore suspect. AUTOVON is thus considered a secondary backup to MINET.

PSN. Finally, EDS will also be able to access switched voice networks in Europe (equivalent to the Bell system in the United States). Again, these circuits are not capable of high speed data transmission. However, the pervasity of the system (over 6000 switches in Germany alone (46:21)) offers excellent survivability features. Modems would also be required to interface EDS micros with this voice system. The entire EDS communications scheme for a typical MOB is depicted in Figure 1.

System Goals. With these communications and computer tools, logistics decision makers will have the capability to make theater distribution decisions, based on near real time information, within two hours (19:8). That is, the time from receipt of the user's request to receipt of shipping



IWS - INTELLIGENT WORK STATION
PTR - PRINTER
■ - DIAL MODEMS (CLASS "C" - MINIMUM REQUIRED "2")
X - APPROPRIATE INTERFACE REQUIRED
● - SWITCH

Fig 1. EDS Main Operating Base Communications Configuration (45:9) instructions at a MOB that has the asset will not exceed two hours. Because the process is automated (very little human intervention), the potential for error or hoarding of assets is minimized. To see how this process works and how the three EDS components interrelate, an example is presented.

EDS Processing -- An Example. Figure 2 depicts the general EDS-C^3I decision flow. If MOB A has an aircraft down because of a broken hydraulic pump, the unit supply clerk fills out an AF Form 2005, Parts Request Document, requesting the part. The request is input to the SBSS computer. If the part is on-base, the request is filled and processing stops. If it is not on-base, base supply notifies the unit, which either cancels the order or revalidates the requirement. If the user validates it as MICAP and base supply reconfirms it is not on-base, the request is backordered and EDS gets involved.

The Log-C^3I system first checks the USAFE Stock Number User Directory, which lists potential sources in-theater for an F-15 hydraulic pump. At this point, the system can take two routes based on USAFE Director of Logistics guidance: complete automation and/or LRC intervention.

If the process is to be automated, the C^3I micros make pump-availability inquiries to the micros serving the MOB's identified in the SNUD check. If say four of the MOB's in the EDS network have the part on hand, C^3I will automatically send shipping instructions to the base closest to the requestor. No negotiations take place; no human intervention

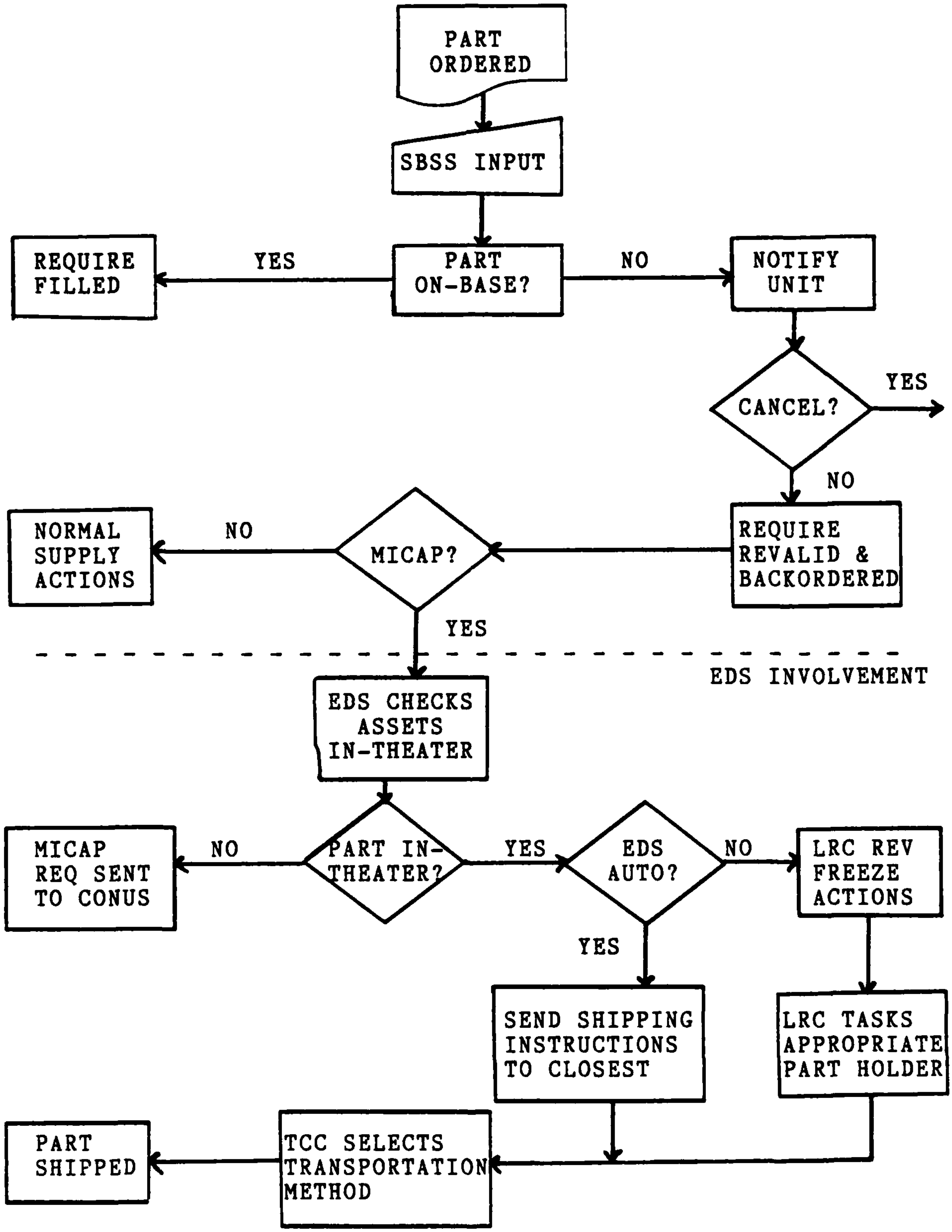


Fig. 2 EDS-C^3I Decision Flow

is called for except to pack up the part. It does not matter whether the pump was part of benchstock, WRSK, or mission support kits. It must be shipped via the mode and priority specified by the LRC's Transportation Control Cell (TCC). If the appropriate hydraulic pump is not available in theater, C^3I automatically sends a MICAP requisition to the CONUS source via MINET or AUTOVON.

LRC intervention allows the LRC to protect assets based on a variety of factors, for example protection by base or stock number. Thus the LRC could freeze all F-15 hydraulic pumps in the theater or on a particular base, thereby protecting a specific asset. Similarly, it could freeze all assets of a particular unit if requested. Freeze tables are updated periodically and disseminated to the C^3I data bases (21:16-18).

The C^3I system does not directly query the EDS warehouses. If the F-15 pump is not in-theater, C^3I automatically notifies the CONUS ALC. The ALC, in turn, can query and source the EDS warehouse through its standard ADP systems. If the pump is available at, say Zweibrucken, the ALC sources that warehouse to ship the part via the EDS aircraft (9:).

Upon receipt of the shipping instructions, base transportation acquires the part, packages it, takes the package out to the EDS aircraft or appropriate terminal if non-EDS aircraft modes are used, helps load it as required, and updates the C^3I data base (21:19).

The Transportation Control Cell (TCC) of the LRC is responsible for selecting the most appropriate means of transportation. If the F-15 hydraulic pump is sourced from a base relatively close to the requestor, surface transportation might be more appropriate than EDS aircraft. However, in most cases, EDSA will be used (21:18).

EDSA will operate in a "hub and spoke" configuration, delivering parts in 12 to 36 hours despite combat conditions (31:1). The hub is tentatively identified as Zweibrucken. EDSA will pick up and deliver to all USAF location spokes, including forward operating locations, warehouses, collocated operating bases, and MOB's.

Potential Problems. On paper, EDS looks promising from both a performance and economic standpoint. However, as with any new system, there are undoubtably many holes that will turn up with system implementation and some that are known today. Among the latter group, a few are presented here.

User Acceptance. As with any new automated system, problems with user acceptance are possible. This is especially true in a situation such as that described above where important assets that were considered the exclusive property of the owning organization must now be sacrificed for the good of the whole. This sacrifice will often require a blind faith in an unproven automated system that at times seems to be taking the very parts a commander may need to keep his own airplanes flying. Hopefully, the payoff will come when that commander runs out of assets himself and the system responds quickly with a part from some other organization.

User Conflict. EDS was designed primarily to support tactical air, critical spares requirements. Other USAF organizations, including SAC, the intelligence community, and tactical air control system elements, may express a strong desire to use this service. Perhaps even non-USAF units may ocassionally request space-available service. Where is the line to be drawn and by whom? More specifically, where do the priorities lie when many users are pushing their urgent requirements?

Survivability. System survivability is also a concern. Warehouses will be dispersed but unprotected. The EDSA will also have to operate unprotected in a very hostile environment. Communications systems are redundant but far from invulnerable. Since EDS is also a peacetime system, planners must continue to work this survivability problem and guard against being lulled into a false sense of security while the system runs smoothly in a non-hostile environment.

Collocated Operating Bases (COB). Finally, as noted above, the lack of a viable EDS C^3 system below the MOB level is a major deficiency. With over 70 potential COB locations (60:72), a tremendous amount of critical spare parts are relegated to the old telephone system identified earlier.

The basic premise behind the COB concept is that there is simply not enough room nor aircraft handling capability at existing MOB's to accommodate the nearly 2000 additional aircraft deployed from the CONUS to support a European war.

The plan is to base these aircraft at airfields owned and operated by the NATO allies. This not only provides them a beddown, but also disperses them from attack and forces interoperability of tactical operations between the U.S. and its allies (60:71). During peacetime, no U.S. forces operate at these COB's except for exercises.

For command and control puposes, tactical forces are assigned to NATO upon outbreak of hostilities (termed CHOP for Change of Operational Control), responding to appropriate NATO C^2 headquarters. However, logistics and administrative support for chopped forces remains a U.S. responsibility. Each COB is therefore assigned a MOB which provides this support. In practical terms, this means that COB's must use certain supply and communications facilities of its host MOB as will be shown later.

One other important entity that needs to be identified is the Wing Operations Center or WOC. (The use of the word "Wing" should not be construed as dictating the size of a unit or its identity. A WOC could be theoretically composed of 7 aircraft of different types from different peacetime units.) Each COB/MOB has at least one WOC whose responsibility is to coordinate all flying and support activity. This is the nerve center of the tactical unit where missions are scheduled and planned, intelligence gathered and disseminated, and crews are briefed. It is at the WOC, or certainly close to it, where the majority of the unit's C^3 capability must exist (39:4-6).

The consequences of not extending EDS C^3I down to the COB level are profound. The effect is to virtually nullify one of the major goals of EDS -- to bring all critical spares into an automated pool of theater resources. An EDS/SPO representative estimated that over 70% of the total aircraft available in-theater at the outset of hostilities would be located at COB's (17). With the amount of critical spares each unit brings with them during and shortly after deployment, the implications for EDS are obvious. The problem for EDS is complicated by the fact that planned communications into these COB's are quantitatively very limited, and those circuits that are available are provided primarily for air tasking orders, fighter scramble circuits and the like. Similarly, the proliferation of C^3 systems at the WOC level has caused space, training, and time utilization constraints. More will be said about these subjects later.

Scope of the Research

As indicated above, there are numerous potential problems with the European Distribution System. A study by Major Richard Poff entitled "EDS -- Is There a Better Solution?" (55:) pointed out these and other major limitations to the proposed EDS system and recommended alternatives. Among his conclusions was that the Federal Express Company may be able to perform the EDS mission as effectively and at a smaller cost than the proposed military system.

The purpose of this research is not to substantiate or refute any portion of the existing EDS program. The implementation stage of the Log C^3I network is well underway and must be taken as a reality and a baseline from which to work. As such, this study focuses on the best ways to build on to an existing network, not on whether or not that network is an optimal one under the circumstances. If, on the other hand, better methods of accomplishing the Log-C^3I mission are uncovered during the research phase, they will certainly be pointed out. Likewise, the merits of EDS system procedures (for example, the computerized reallocation of a unit's assets) will not be debated here, although there is undoubtedly fruitful ground to examine in this critical area. The ultimate recommendation(s) for extending the EDS C^3 network to the COB level will, therefore, be constrained to interfacing with the existing system.

Ideally, the alternatives presented should be evaluated using criteria established not only by the designers of the system but the intended users as well. However, at this early stage in the Log-C^3I subsystem development, the user community has not been adequately identified and trained to solicit their inputs. Thus, the evaluation process will necessarily depend heavily on the technical community (e.g., the EDS System Program Office) for help in establishing evaluation criteria although the actual analysis of alternatives using this criteria will be independent. Once operational experience is gained on the EDS C^3I system, it may be useful to reexamine, together with the user community, the propriety of the evaluation criteria used in this study.

This study is confined to integration of EDS C^3I only at the COB level. The EDS System Operational Concept calls for Log C^3I to be deployable to "all theater locations where logistics functions take place." (21:26) Many aircraft are capable of conducting operations from so-called bare bases or forward operating locations (FOL) which have little in the way of power and water, let alone C^3 facilities. Because of this total lack of an infrastructure on which to build and the relatively small numbers of aircraft involved compared to the COB integration problem, this portion of the EDS implementation program will be left to future researchers.

Research Questions and Objectives

As indicated earlier, the objective of this study is to identify alternatives for extending the EDS Log-C^3I subsystem down to the COB level. In order to do this, the following questions must be answered: 1) Of the total amount of critical spare parts located in the European theater, how many will be positioned at the Collocated Operating Bases? 2) Did the study that justified developing EDS include COB assets and airplanes? 3) What present C^3 systems exist at European COB's? 4) What C^3 systems are planned or under development? 5) Can a COB-level EDS subsystem be integrated with any of the above systems? 6) What other technological alternatives exist? 7) Based on a set of criteria, what alternatives identified above are optimum for the EDS COB level?

II. Methodology

General

The primary goals of this research effort are to determine whether extension of the EDS C^3 system down to the COB level is warranted and, if so, what are the best ways to accomplish it. The investigative questions presented in the previous chapter require somewhat different research treatments. However, the general methodology for answering most of these questions remained the same -- to collect information from published and unpublished Air Force sources and conduct personal inquiries and observations where appropriate. The nature of the questions required collecting objective data concerning, for example, the existance of C^3 systems, their specifications and capabilities, and the technical feasibility of interfacing them with EDS. Once that data was collected, candidates were evaluated using a set of objective and subjective criteria. The general methodology for this research is depicted in Figure 2. A detailed discussion of each step follows.

Determining the Scope of the EDS COB Problem (Step 1)

This first step attempts to resolve research questions 1 & 2 (pp. 27-28). Question 1 stated that it was important to get a feel for the number of critical spares that might be located at the COB's in comparison to those located at the Main Operating Bases. As implied by the 70-30% COB to MOB aircraft positioning ratio and the fact that many critical

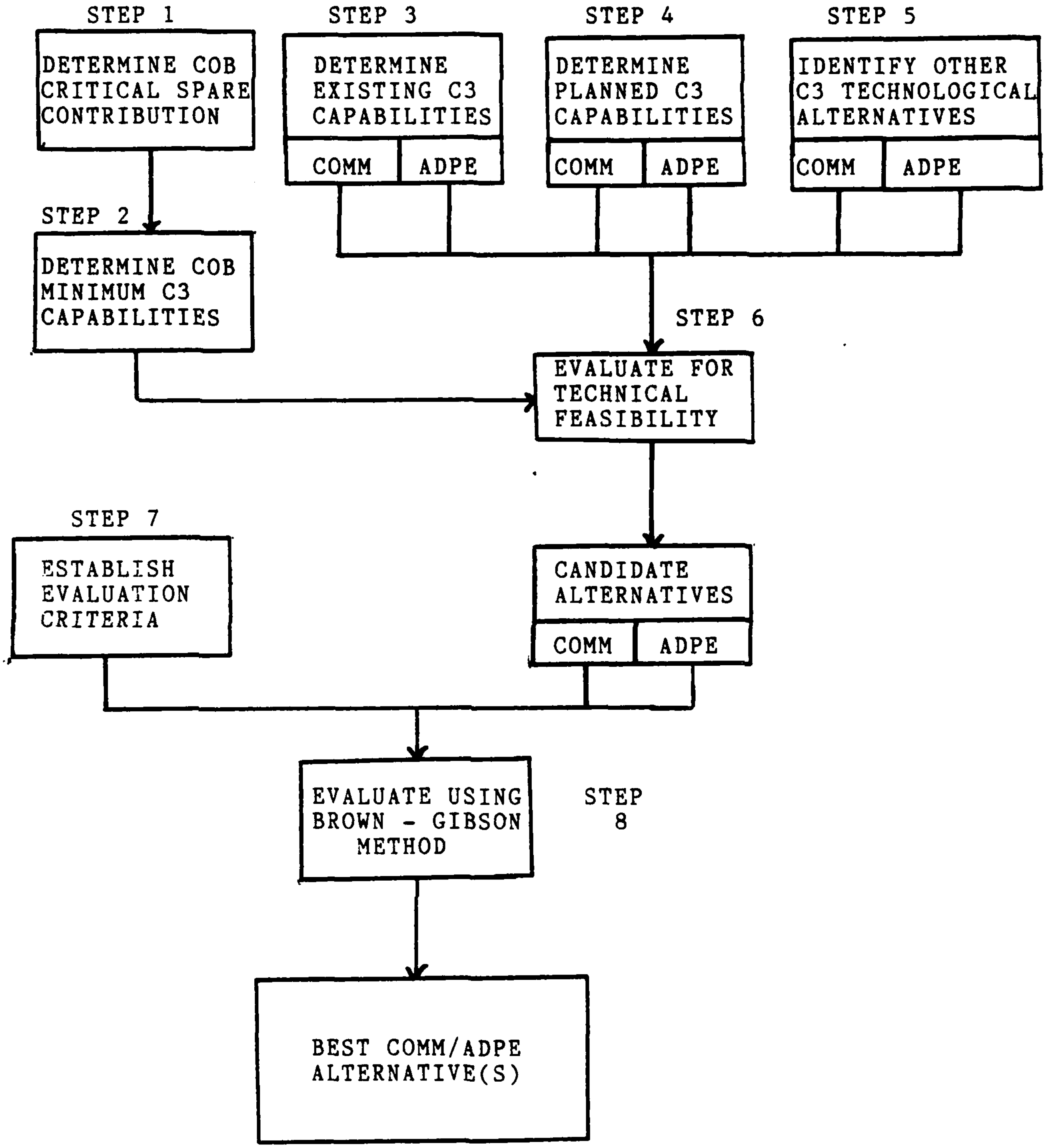


Fig. 3 Methodology Overview

spares are deployed with a unit in their WRSK kits, the amount of assets of concern to EDS that will be located at the COB's could be substantial. In order to obtain this kind of data, two sources were considered primary: 1) Personnel in Headquarters, Air Force Logistics Command's Warplans and Analysis Branch, in the process of reevaluating their COB logistics support concepts, supplied information concerning the planned number of aircraft and amount of WRSK material to be located at NATO COB's and MOB's. 2) Telephonic conversations with supply officers from Headquarters, Tactical Air Command were used to confirm unit WRSK kit assessments provided by AFLC. Together, these two sources provided meaningful estimates concerning the amount of critical resources available at the COB level.

Since the primary justification for the EDS program came as a result of an extensive RAND Corporation study, research question 2 pointed out that it was important to determine whether the study's baseline for identifying the impact of an unresponsive distribution system included aircraft and/or spare parts located at the Collocated Operating Bases. If the study included the COB's and the proposed EDS C^3 system does not, the new system's ability to return a majority of the projected number of grounded aircraft to flying status must be questioned. Making this determination was relatively simple -- acquire the specific RAND study and analyze it for COB applicability.

Determining COB Minimum C^3 Capabilities (Step 2)

Before any alternatives could be compared, a minimum acceptable capability had to be established for the new COB C^3 subsystem. Two possible configurations for the COB system were developed in conjuction with the EDS System Program Office. System capabilities were thereby dictated by each of these configurations. As an example, Configuration 1 might require a certain amount of memory capacity while Configuration 2 might require a different amount. Similarly, software requirements, communications capabilities, and computer hardware requirements were also determined in large part by the system configuration. Thus, two sets of minimum criteria were established based on possible system configurations.

Determining the Existing COB C^3 Structure (Step 3)

Most C^3 systems can be broken into two parts for analytic purposes: an Automated Data Processing Equipment (ADPE) segment and a communications subsystem. This approach was used in evaluating EDS alternatives for the COB C^3I subsystem. Steps 3, 4, 5, and 6 (corresponding to research questions 3 through 6) treats ADPE and communications options separately, attempting to discover the best alternative(s) from each of these areas. This approach, in addition to being technically justifiable (ADPE can use a variety of communications mediums simultaneously), is also functionally expedient, since nearly all organizations have separate, but closely interdependent branches to deal with these two areas. The communications and ADPE alternatives selected through this analysis would then logically be synthesized into a proposed COB C^3 system.

The Air Force Communications Command (AFCC) and its European subordinate, the European Communications Division (ECD), are the primary agencies responsible for communications planning and procurement in this region. Based on the author's prior work in the NATO C^3 area, it was known that these organizations had developed COB contingency plans, detailing a standard communications "package" for use by most COB's. This information was requested and received from HQ AFCC. Actual by-location circuit plans were also available from these sources if required.

The office of primary responsibility for United States Air Forces in Europe (USAFE) *command and control matters* is USAFE/DCZ. This division maintains plans on existing capabilities as well as future initiatives and improvements. Written and telephonic contacts were made with this office and initial information concerning USAFE automation projects was received.

Identifying Planned COB C^3 Systems (Step 4)

As mentioned before, there are many ways to connect ADP equipment. Communication systems can be divided into terrestial and space segments. Several improvement projects and new initiatives that apply to the European theater are being developed by various agencies concerned with these two segments. Once again, HQ AFCC was the focal point for these projects. Contacts were established and information was gathered from this and other agencies, particularly Space Command and the Defense Communications Agency (DCA), concerning projects such as the Military Strategic-Tactical and Relay (MILSTAR) satellite program and the Defense Data Network (DDN). This information was analyzed for its applicability to the COB EDS problem. Information concerning the general availability of public communications services to European COB's as well as the economic costs associated with increasing leased circuitry to handle a possible EDS C^3 extension to the COB's was provided through several recent RAND studies.

As previously mentioned, automation efforts to improve fighter unit information processing have been initiated by USAFE. Under the project nickname "SALTY CONTROL," USAFE/DCZ is presently coordinating two projects: development of a C^3 testbed at Spangdahlem AB, GE, whose purpose is to integrate a plethora of unit level automation projects, and a similar program at RAF Lakenheath, UK, undertaken as a Wing Commander's initiative. More will be said about these programs in subsequent chapters of this study. Research efforts concentrated on determining the capabilities of these proposed systems in terms of communications connectivity, memory capacities, and operating systems and protocols. Other information relevant to the technical feasibility (specific criteria to be discussed later) of integrating these systems with EDS, such as planned implementation schedules and locations, was also gathered.

The SALTY CONTROL program is also under the auspices of the Tactical Air Forces Interoperability Group (TAFIG) at Langley AFB, VA, whose responsibility it is to coordinate all automation activities of the Tactical Air Forces (TAF), which include Tactical Air Command (TAC), Pacific Air Forces (PACAF), and United States Air Forces in Europe (USAFE). Again, contacts were established with this agency in order to collect information on any other programs that might impact NATO's COB's. Also, as indicated by USAFE/ DCZ, TAFIG had most of the SALTY CONTROL program information and was much more easily accessible than the European offices because of distances.

The Electronics System Division (ESD) of Air Force Systems Command (AFSC) manages Air Force-wide C^3 programs. Contacts were established with ESD offices to determine if any other non-TAF C^3 programs might be applicable to NATO COB's. If so, information was be collected from appropriate system managers.

Finally, information on new, deployable maintenance/supply automation systems under development by Air Force Logistics Command (AFLC) was collected. Programs such as the Combat Supply System, Combat Maintenance System, and Phase IV (each to be discussed later) impact the research problem. System managers for these programs were contacted and information was compiled.

Identifying Other Technological Alternatives (Step 5)

In the communications area, recent literature was be reviewed to determine if new state-of-the-art systems could be applied to the research problem. The Armed Forces Communications and Electronics Association's monthly publication Signal routinely deals with current communications and C^3 topics. Defense Electronics also addresses scientific advances in communications networking. Methods of particular interest to the COB problem included Time Division Multiple Accessing (TDMA), as incorporated in the Joint Tactical Information Distribution System (JTIDS), meteor burst communications, and packet switched radio networks. Each of these and others discovered through the literature review were analyzed for potential application to an EDS COB system.

An obvious ADPE technological alternative is to procure more MOB-type microsystems from the pending EDS C^3I contract for use at the COB's. Additionally, depending on the C^3 configuration chosen, any other type of ADP equipment that met the COB subsystem capability requirements could have been considered. In order to limit the nearly endless possibilities of acceptable equipment brands, two alternatives from existing Air Force contracts were selected as the most feasible representatives of this class. Information concerning these non-EDS microsystems was obtained from Air Force data automation experts (such as those at Wright-Patterson's Aeronautical Systems Division Computer Center) as well as computer trade journals.

Evaluating for Technical Feasibility (Step 6)

The purpose of collecting information on existing and planned automation systems was to determine whether or not the EDS COB C^3 requirement could piggyback onto another system, thereby saving money, training expenses, and critical space in a WOC. Using the minimum capabilities identified in Step 2, each ADPE and communications alternative resulting from Steps 3 through 5 was evaluated from a technical feasibility standpoint. In addition to the technical characteristics required by Step 2, an availability constraint was added, i.e., the proposed communications or ADPE alternative had to be available for EDS use within a reasonable time period which, for purposes of this study, was considered 10 years. Those options that were considered technically feasible were then judged against a set of additional evaluation parameters as described in Step 7. Those that did not pass the technical feasibility hurdle were dropped from futher consideration.

Establishing Evaluation Criteria (Step 7)

Having established a list of feasible alternatives, final selection criteria were determined. The Brown-Gibson technique (Step 8 of Figure 3) permits the use of both subjective and objective evaluation criteria. In this study, economic cost was selected as the only objective factor. Several subjective variables were chosen in coordination with the EDS SPO. These variables and their definitions are given below:

A) Availability: the speed at which an alternative can be implemented to solve the EDS COB C^3 problem.

B) Accessibility: how often during any given day will the system be usable by the EDS operator. This may range from a small daily time slot, to an hourly window, to continuously available.

C) Proximity: the physical closeness of the system to the EDS operator.

D) Political Feasibility: willingness on the part of program managers and funds controllers to adopt the alternative in light of competing requirements and parochial interests.

E) Survivability: ability of an alternative to remain operational during hostilities.

F) Supportability: ease of acquiring maintenance support for the system.

G) Space Requirements: amount of estimated physical space each unit will use.

H) Flexibility: ability to accommodate new requirements or switch to different operating modes.

I) Reliability: the probability that the system in question will perform adequately for a given period of time under the conditions encountered.

Determining Best Alternative(s) (Step 8)

Once technically feasible candidates were identified and evaluation criteria established, the final step was to select the best alternatives using the Brown-Gibson approach. This method can be used for "many complex decision problems where it is necessary to combine subjective and objective factors into an overall measure of preference for each alternative." (15:394) This technique quantifies all the relevant evaluation criteria into an overall alternative preference measure, indicating which of the alternatives evaluated should be selected for implementation.

Objective factor ratings are fairly easy to determine through manipulation of economic costs. Subjective factors are quantified through the use of pairwise comparisons where each alternative is compared to every other alternative within each subjective factor category. For example, ADPE Alternative 1 is compared to ADPE Alternatives 2,3,4 ...n in terms of its availability, reliability, proximity, etc. The preferred alternative within the category is given a "1" while the non-preferred alternative is assigned a "0". If neither is preferred (both considered equal within that subjective factor), both are given a "1". The data is then manipulated to provide a subjective factor rating for each alternative. Weights can also be assigned to each of the subjective factors as well as between the objective and subjective criteria. The objective and subjective ratings are combined to give the overall preference rating. The Appendix provides a detailed mathmatical description of this process and will be referred to in later chapters of this study.

Having provided the background and methodology behind this study, it is now possible to begin the search for viable alternatives for extending the EDS C^3I system to the COB level. Chapter 3 is titled "Findings," referring to Steps 1 through 6 of this chapter. Chapter 4, "Results," takes these findings and applies Steps 7 and 8, resulting in preferred alternatives for the ADPE and communications subsystems of a C^3 solution. Chapter 5 applies sensitivity analysis to these results. Recommendations and concluding remarks are presented in Chapter 6.

III. Findings

Introduction

The focus of this chapter is the search for viable ADPE and communications alternatives for extending EDS to the COB's (Steps three through six of Fig. 3). Completion of this search will yield technically feasible existing, planned, and/or possible C^3 alternatives for evaluation under the Brown-Gibson method. However, before beginning this segment, it is necessary to determine the scope of the distribution problem EDS is suppose to resolve in order to understand the need for a distribution system extending to the COB's. This understanding is the objective of Step 1.

COB Critical Spares Contribution (Step 1)

Justification for the *European Distribution System* was built primarily around Bergman and Carrillo's study which identified a potential daily grounding of over 300 fighter aircraft, translating into over 800 lost sorties per day (4:). Research questions 1 and 2 (p. 28) were concerned with the extent to which the proposed system would reduce these figures. Specifically, does the lack of COB incorporation into the system impact on the ability of EDS to return fighters to operational status?

Several sources state that well over half of the wartime reinforcement US aircraft are scheduled to go to Collocated Operating Bases (66:17). For example, of the 336 F-16A aircraft tasked to support a European war, 264 (includes Tactical Air Command, U.S. Air Forces in Europe, Air National

Guard and Air Force Reserve assets) will be located at COB's (41:). This represents 79% of the F-16 force in theater. How do these percentages relate to critical spares located at the COB's? To understand this, a brief review of wartime spares management is necessary.

To simplify the discussion, wartime spares management can be broken into two segments. Those units that are assigned to Europe in peacetime (e.g., 86TFW, Ramstein AB, Germany) are supported by Peacetime Operating Stocks (POS) plus Base-Level Self-sufficiency Spares (BLSS). POS is simply the spares required to support peacetime operating levels and are acquired through normal base-level ordering procedures. In wartime, an additional number of spares (BLSS) will be required to support increased flying activity. These BLSS authorizations are designed to be consumed at either the peacetime base or a forward operating location (which could be a COB) within Europe.

The other spares category is derived from units deploying to Europe from the CONUS with War Readiness Spares Kits (WRSK). WRSK are deployable packages of spares designed to completely support a unit for a specific period of time (usually 30 days). It is assumed that after this specified time, the normal resupply system will have caught up to sufficiently support the deployed unit. In addition to WRSK, some units have their own deployable field maintenance equipment, shelters, and people. This additional field maintenance element deploys after the aircraft and their WRSK, and

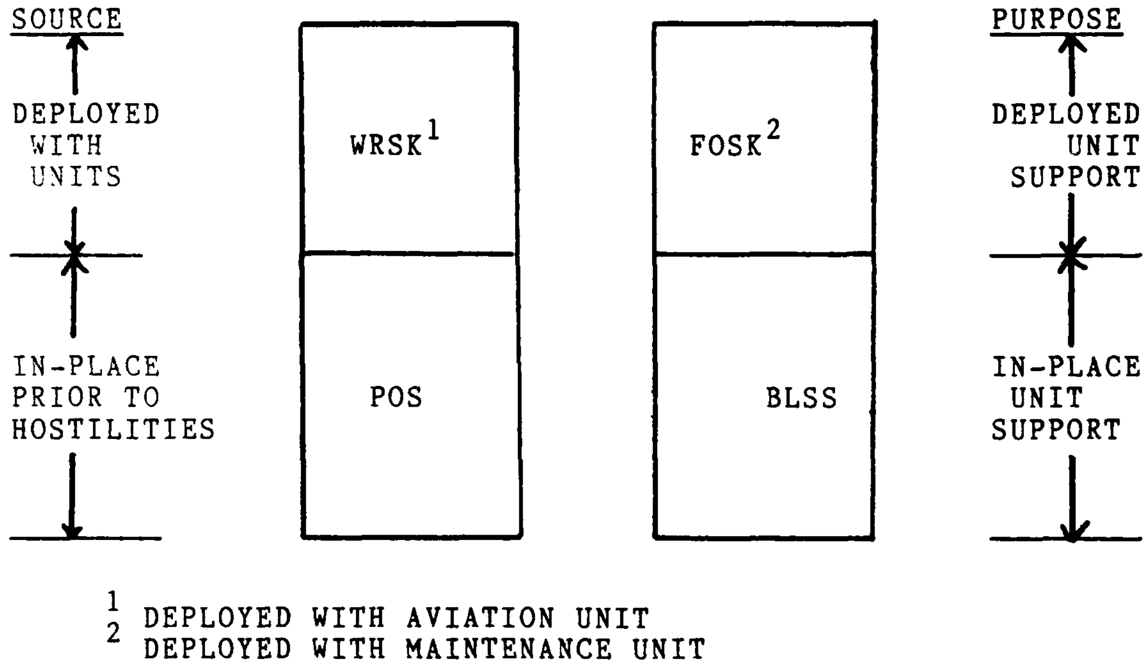


Fig 4. Spares Segment Relationships (59:31)

carries with them Follow-on Spares Kits or FOSK. The FOSK is designed to augment the WRSK, providing an additional level of sustainability until resupply can be affected (59:31). The relationships among these various spares segments are depicted in Figure 4.

To garner some idea of the size of these spares segments, a typical deploying F-15 unit with 24 Primary Assigned Aircraft would carry 4500 items in its WRSK. Similarly, an F-16 unit would stock some 4700 items in its WRSK (23:). If these figures can be assumed as being typical WRSK quantities, the number of spare parts contained in the WRSK kits of the nearly 2000 deploying aircraft is undoubtably over 300,000. Although some of these aircraft will be deploying to Main Operating Bases, the relatively small amount of WRSK they take to the MOB's will be more than offset by the BLSS taken to COB's.

Since the EDS C^3 subsystem is presently limited to MOB's, it will have reliable "visibility" over POS and BLSS assets only. That is, EDS computers will have access to POS/BLSS information (quantities, stock numbers, etc.), but not to current data of deployed WRSK assets. (Subsequent sections of this research describe the inadequacies of the present WRSK computer card deck system for identifying WRSK assets to a host base supply computer.) The central issue thus comes down to this: How large is the WRSK/FOSK pool of assets relative to the POS/BLSS quantities? According to representatives of Hq AFLC: "If critical spares are defined as POS, BLSS, and WRSK, the percentage of critical spares that will be deployed to COB's is the same as the percentage of aircraft deployed to those COB's." (41:) Essentially, this implies that the amount of POS/BLSS that is required to support an aircraft is equal to the amount of WRSK required to sustain that aircraft over equal periods. Furthermore, it implies that well over half (and for some weapons systems, nearly 80%) of the theater's critical spares will be virtually uncontrolled by EDS because of their location at COB's.

In order to adequately answer Research Question 2 (i.e., Did the study that justified developing EDS include COB assets and airplanes?), it is essential to understand some of the underlying assumptions behind the study that provided the thrust for funding EDS. If, for example, the 300+ grounded fighters identified in the study were all located at Main Operating Bases and inoperative as a result of the lack of an assured distribution system between the MOB's, certainly the present form EDS system would go a long way towards returning these aircraft to the battle. However, that is not the case. The figures of restored aircraft cited by Bergman and Carrillo are based on full CONUS deployment and included operating aircraft at the COB's (5:). The assured distribution system must be extended to the COB's in order to significantly reduce the projected number of lost sorties.

Minimum COB C^3 Capabilities (Step 2)

Having shown that a significant portion of the theater's critical spares are to be positioned at Collocated Operating Bases, attention can be turned to Step 2 of the research algorithm, determining the minimum COB C^3 capabilities. Of primary interest here is the COB computer's capabilities and the environment in which it must operate in order to accomplish the objectives of EDS. Listed below are the two most likely computer configurations for interfacing into EDS:

Configuration 1. Figure 3 depicts the COB system acting as an autonomous EDS processor with intersite communications capabilities similar to that of the MOB processors. In this configuration, the EDS processor functions as an on-base Standard Base Supply System (SBSS), its WRSK items making up its supply assets. Each COB system should also be capable of inputing and updating its WRSK availability information in

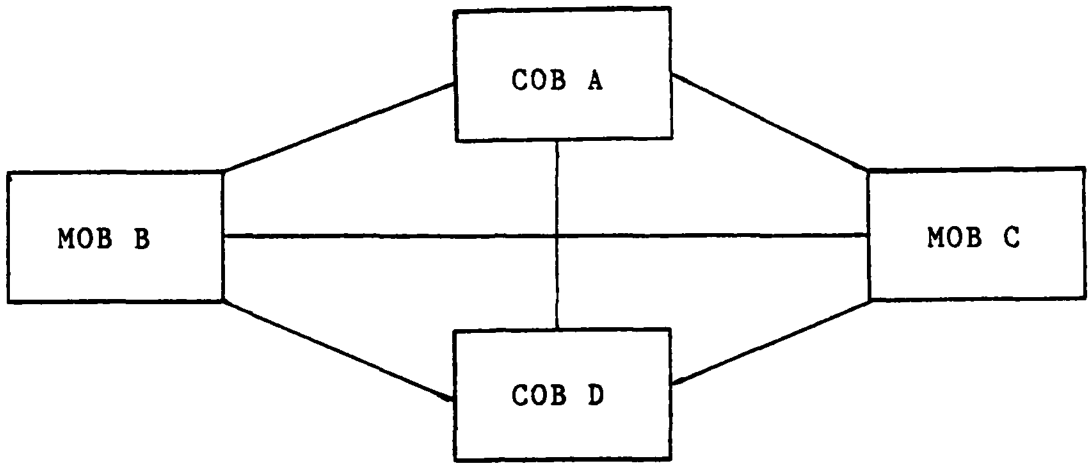


Fig 5. COB Configuration 1

their host base SBSS account in order to maintain centralized management control of supply accounts. (See Combat Supply System discussion, p. 55) Thus, with the exception of the SBSS spares back-up file, the COB processor would have the same files and application software as the MOB units. The elimination of the spares back-up file requirement would reduce the internal storage requirement from over 84 MB to less than 35 MB. Associated hardware (printers, modems, disk devices) similar to the MOB package would be required.

In this configuration, each COB processor would act independently of and identical to the MOB EDS micro -- making and responding to inquiries, transmitting and receiving shipping instructions and confirmation notices, etc. In effect, each COB processor would be a stand-alone and distinct element of the EDS, equal in EDS processing terms to the other MOB terminals. The advantages of this configuration include:

a) Potential reduction in computer resource sharing problems including access to files and software.

b) Fewer "nodes" when compared to Configuration 2, (discussed below) since each COB processor is independent of its MOB host. Fewer nodes enhance survivability of the system.

Disadvantages of this option include:

a) An increased data communication requirement. Additional interfaces, modems and switches would be required to set up a redundant communications network similar to the MOB's.

b) Increased *applications* software and storage requirements when compared to Configuration 2 below.

c) Increased maintenance and associated logistical networks to support the redundancy.

Configuration 2. The COB micro acts as a long remote off its host base EDS processor, as depicted in Figure 4. In this configuration, the COB terminals share the software and files of the host processor with other MOB-based EDS terminals. Inquiries, confirmations, and shipping instructions would originate from the MOB processor using established MOB communications (MINET, PDN, AUTOVON, PSN). A capability to input and update WRSK assets into the host base SBSS would still be required (See Combat Supply System discussion, p. 55). The COB to MOB processor link would have to be a

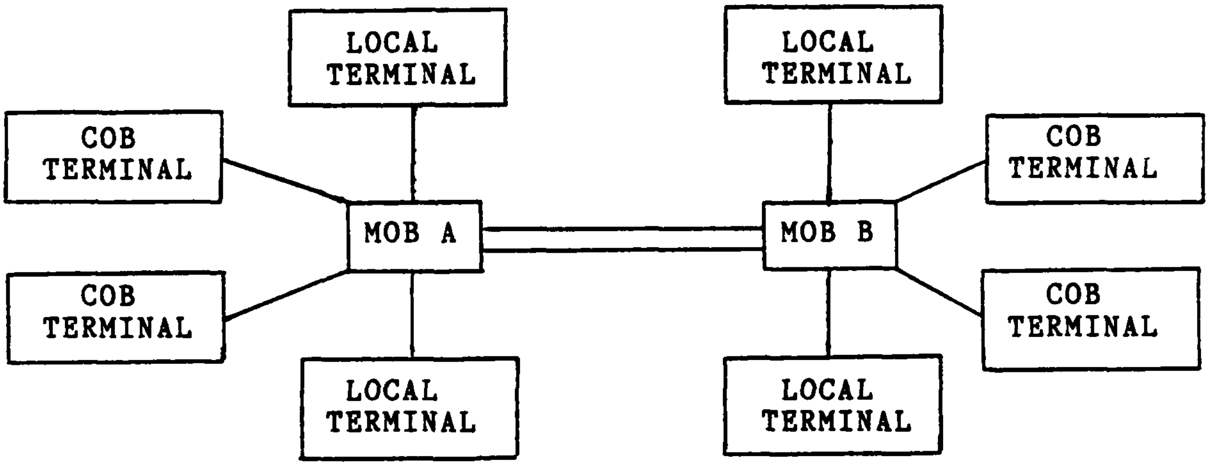


Fig 6. COB Configuration 2

continuously available circuit in order to make automatic inquiries to respective data bases. A separate printer would be required. Advantages of this configuration include:

a) Greatly reduced on-line storage and software requirements (less than 1 MB).

b) Possibility of using "dumb" terminals to satisfy the requirements.

Disadvantages include:

a) Communications interface complications (e.g., interfacing COB to MOB link with appropriate PDN protocols).

b) Host processor software and files access problems.

c) Possible increased communications software requirements.

d) Decrease in EDS system survivability because of dependence on MOB "nodes" for COB transactions.

Either of these two configurations allows the COB automated data processing equipment the potential for performing all the EDS C^3I functions described in the System Operational Concept. It would be possible to provide a reduced capability at the COB, such as restricting the ability to source other bases for their requirements. However, since the concept does not include such restrictions, the configurations associated with a reduced capability will not be addressed.

To be acceptable, alternative solutions for including the COB's into the EDS network must meet the minimum requirements of one of these two possible configurations. With these guidelines in mind, it is possible to examine potential alternative candidates for use in the EDS program. The next section begins the systematic examination of these alternatives. As mentioned previously, candidates are distilled from existing and planned systems as well as other technologically possible solutions. Each candidate is analyzed in terms of the criteria discussed in Chapter 2.

Existing COB C^3 Capabilities (Step 3).

In this section, C^3 systems that are either physically in place today or are programmed to be activated in the case of war are considered. "Programmed" is dintinguished from "planned" in that programmed systems have been approved, funded, and integrated into the pool of available assets for war-planning purposes. Planned systems are those under development that have not been totally funded or deployed in the operational Air Force.

Under present planning concepts, C^3 systems at the COB's are made available in three ways (33:1). First, on-base communications are expected to be provided by the host nation. These systems would include base telephone, single purpose circuits (hotlines), and public address systems. If the host could not provide these services, USAFE would make up the difference. Second, off-base connectivity is a U.S. responsibility. Systems programmed in this category include: one AUTODIN terminal and 300 baud circuit; one small switchboard terminating four circuits (two lines between the COB and its sponsor base, one circuit between the WOC and the appropriate NATO tasking authority and one 4-wire, European-area access AUTOVON circuit extended to each Squadron Operations area); two UHF radios for air-to-ground use; an HF single sideband radio for long-range, backup communications to the sponsor base; and "Base Supply computer remotes [that] will extend the sponsor unit computers to selected COB's." (33:2) The communications lines for these computer remotes will be "activated after mobilization." (33:2)

The final source of C^3 systems is the user-unique, ADPE-intensive systems that must be deployed with the functional user. Integration of these ADPE-based systems with theater communications networks would be the responsibility of the end-item users. A large number of systems fall in this category and are discussed in the planned systems section of this chapter. Figure 5 depicts the existing COB C^3 structure.

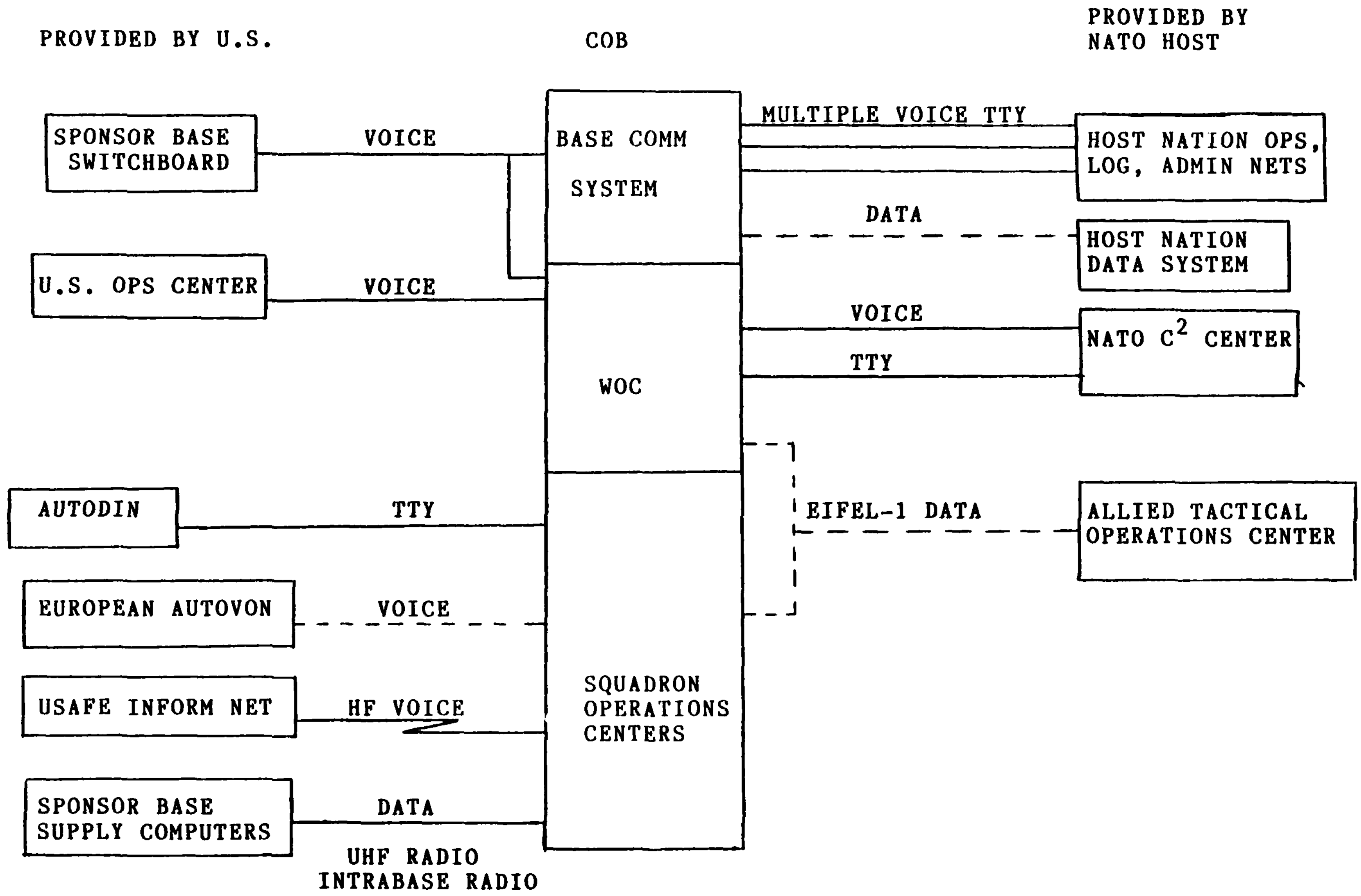


Fig 7. Existing Collocated Operating Base C^3 Structure (33:)

ADPE Candidates. Of the existing ADPE systems, only one significant possibility impacts the EDS COB problem: the US-provided base supply computer remote. This particular system seemed worthy of in-depth exploration because of its obvious relation to the logistics field. However, conversations with HQ Air Force Communications Command (AFCC) personnel (56:) indicate that less than 10% of the COB's will be served by these remotes. In fact, as of the date of the conversation, only two COB's were identified for this service and neither Hq AFCC or ECD knew of any projects to extend the program. This may be due to the planned deployment of Combat Supply System (CSS) microcomputers which will be discussed later. Thus, from an ADP equipment standpoint, existing systems do not provide any piggyback potential for the EDS program.

Communications Candidates. On the other hand, several possibilities surface from existing communications systems. First, since most COB's are merely peacetime allied airfields, commercial data and voice common-user systems are available. Secondly, any of the four off-base circuits, with the possible exception of the ops-to-tasking agency line, could be accessible by an EDS component through either dial-up procedures (in the case of the AUTOVON circuit or, depending on their configurations, the two interswitchboard circuits) or a restructuring of the interswitchboard lines themselves if straight through access was not possible. Finally, radio communications could be employed through possible ground-air-ground data relay in the case of UHF radio or direct, long-range HF connectivity. These three systems are evaluated in subsequent portions of this study.

Planned COB C^3 Capabilities (Step 4).

This section explores developmental ADPE and communications systems that impact the COB and EDS environment. Once again, the intent is to discover possible EDS integration potential for systems designed for use at the COB's. ADPE systems will be examined first.

ADPE. Many deployable, microcomputer-based C^3 systems are under development for use in the European theater. The proliferation of these systems is of such a concern to USAFE authorities that a separate C^3 program has been established to deal with the problem. This section outlines those systems with the greatest piggyback potential for EDS. Intelligence systems and NATO command and control subsystems were not considered due to prodigious interface and access problems. The discussion must start with the USAFE integration effort under the code name, CONSTANT CONTROL.

CONSTANT CONTROL. The primary purpose of this program is to "integrate ADP assists at the wing/squadron level" (66:) thereby improving the flow of information at a European air base. USAFE recognized the trend by functional specialists to improve wartime efficiency through the use of automation. They also detected a lack of coordination and integration among the various system developers, with the result being a multitude of independent and autonomous systems, limited in scope and destined for use in a flying unit's operations center, i.e., "a large number of top-down driven vertical C2 information systems with little or no horizontal integration." (66:) By late 1983, USAFE had counted at least 19 separate, ADP-based systems under development for use at the Wing/Squadron unit, many of them concentrated in the WOC. With this kind of proliferation in such a small area, the potential for increased efficiency through automation was quickly being eliminated.

USAFE's approach for dealing with this problem is to develop standardized terminals that will interface with the various systems through local area network (LAN) technology. LAN's provide a means of connecting distinct data bases and systems within a limited geographical area, thereby facilitating the sharing of data and computer resources. To develop this capability, USAFE is establishing a testbed at Spangdahlem AB, Germany, whose objective is to "provide horizontal connectivity at the unit-level and to develop requirements for a common family of ADP hardware and compatible software." (36:)

To place this program in perspective, USAFE's intention, at least in the initial stages, is to reduce the number of <u>terminals</u> (i.e., video screens) in the WOC by having one or two standardized units tapping each of the nineteen or so functional area computer systems. Thus, for the near future, CONSTANT CONTROL will have little impact on the acquisition of hardware or development of software capabilities by functional users since the testbed will only integrate what is available at a base, not provide a distinctly new capability. In the far term (perhaps 1988 and beyond), the testbed program may develop a system that houses all functional area software requirements needed at the Wing/Squadron level in one piece of ADP hardware, resulting in complete peace and wartime ADP integration.

Wing Operations Management Information System (WOMIS). Independent of the CONSTANT CONTROL program, the 48th Tactical Fighter Wing at RAF Lakenheath, United Kingdom, has also undertaken the task of attempting to evaluate available automation alternatives (36:). Similar to CONSTANT CONTROL, WOMIS employs a testbed in an effort to reduce the over abundance of planned unit-level automated systems.

Combat Supply System (CSS). The CSS is essentially a microcomputer-based, transportable system that will provide automated supply support for "War Readiness Spares Kits (WRSK), Mission Support Kits (MSK), Follow-on Spares Kits (FOSK), mobility equipment and War Reserve Material (WRM)." (70:) The CSS is designed to reduce the problems associated with providing adequate "visibility" of deployed spares to the host base SBSS. The reduction of these visibility problems is possible because each microprocessor will contain SBSS-compatible records of WRSK items (including quantity, stock number, etc.) and will have an external communications capability with the host SBSS. Each CSS will be capable of operating from "temporary, unconditioned shelters" (70:) and will come with its own ground power generator. Present plans call for procurement of 70 systems to support all deployment-tasked USAF units. The Borroughs Corporation has been selected as the contractor for this program and the B25/26 systems as the baseline hardware (68:). The contract calls for inclusion of an option to buy 240 additional systems based on Deployable Core Automated Maintenance System requirements, to be discussed in the next section.

Specifications for the CSS include: 60 MB of non-removable disk storage; 2 MB storage capcity per removable, 8 inch diskette; 2400 to 9600 bit per second communications capability; and contractor-provided modems designed to interface with the Phase IV SBSS. Software will be limited to database management routines and generation of standard products for use by operators and the host base SBSS. (30:)

Deployable Core Automated Maintenance System (DCAMS). Like the Combat Supply System, the DCAMS is envisioned as a logistics management tool for a deployed force. However, the scope of the proposed DCAMS capabilities is much broader than the CSS' spares tracking requirement.

Essentially, DCAMS is designed to provide deployed logistics managers with the same or similar capabilities they have with their Maintenance Management Information and Control System (MMICS) used during home-base operations . MMICS is a computer based system used at the home station to track aircraft engine wear, generate inspection schedules, record needed maintenance action, and manage personnel training and equipment transfers. In a study completed in 1982, the Air

Force Logistics Management Center reported that Air Force major commands require "some" of MMICS capabilities (particularly engine tracking) immediately upon arrival at the deployment location, "most" of MMICS by Day 15, and "all" of it after Day 30 (16:ii). Manual upkeep of this information was deemed impossible in a wartime scenerio (16:9). Thus, the requirement for a mobile equivalent of MMICS resulted in the DCAMS program. Although primarily developed with the tactical fighter unit in mind, the USAF Data Project Directive (DPD) also directs design and development of DCAMS to support all other aircraft as well as cruise missiles, munitions, test equipment, communications-electronics equipment, and other missions (35:).

Phase IV. In this study, the author makes several references to the Phase IV Base Supply modernization program. A brief summary of the project is presented here to show its applicability.

Phase IV is a $1.8 billion program to replace existing standard base supply system (SBSS) computers with new, Sperry Corporation 1160 computers. A total of 153 such systems will be installed at Air Force installations worldwide, serving over 7000 remote terminals. The system will be used to track aircraft, missile, and other war reserve material spare parts. Not only will the new computer serve the supply/logistics spectrum, it will also keep records on aircraft maintenance, transportation, and base personnel. Additionally, financial accounts and "other areas of business conducted daily at bases around the world" will be handled by the Sperry 1160's (22:6). Essentially, the Phase IV computer will be the central processor for most of the data routinely handled on a base.

For EDS purposes, no Phase IV remotes per se have been programmed for Collocated Operating Bases. According to Phase IV officials at Gunter AFS, Alabama, CSS terminals will serve this function (44:).

Tactical Air Forces (TAF) Small Computer. For several years, the Air Force has recognized the potential for microcomputers to act as aids in tactical mission planning. As early as 1977, this author was involved in the initial effort to automate the Tactical Air Control Center through the use of a deployable IBM System 34. Since that time, many changes have occured in the Tactical Air Command's (TAC) approach to automation. As part of that evolution, TAC has established a contract to buy Crememco microcomputers for use by their units in flight planning, weapons delivery, penetration aids, and other "logistics, personnel, medical, and safety" (34:1-1) requirements. To date, over 1100 machines, most configured for deployment, have been procured by TAC units. Mission planning software is being developed under contract while other functional area software development has been the responsibility of the individual unit.

The Crememco's purchased under the TAC contract come with dual disk drives, the Z-DOS operating system, and an RS-232 interface for external communications. Most units have ordered Winchester hard disks, providing a directly accessible on-line storage capacity of over 20 MB.

Although procurred primarily with the mission planning function in mind, the need to "inventory aircraft, personnel, and material" (34:1-1) has also been recognized. TAC logisticians are actively engaged in the development of logistics applications both for peace and wartime purposes (65:). In order to incorporate EDS software into the TAF Small Computer program, the TAC logistics community would have to be sold on the need and feasibility of such an integration effort (38:).

Combat Logistics System (CLS). Just as the supply and maintenance arms of the logistics functional area have developed automated support programs, the logistics war planning community is also actively engaged in obtaining an automated information system.

Logistics warplanners have automated the identification of equipment quantities and types, as well as their unit sourcing, for use in the development of specific warplans. This is done with software available through base computer mainframes. Similarly, the capability to automate the planning of aircraft loads with a microcomputer was very effectively demonstrated during the Grenada operation using the Deployable Mobility Execution System (DMES) software package and a Hewlett-Packard microcomputer. CLS is an attempt to combine these capabilities into a deployable, standard microprocessor to be used Air Force wide.

Funding has been obtained beginning in FY85 to provide a Zenith Z-100 microcomputer with DMES-based software capabilites to each mobility-tasked Air Force unit. As detailed below, the Z-100 has been selected as the standard Air Force personal computer. The capability to interface with a Sperry 1100/60 Phase IV computer will also be resident. Software to accomplish these features is being developed by the project office at Gunter AFS. Individual systems with direct access storage capabilities up to 20 MB are envisioned (63:).

Communications. Although upgraded equipment is being procurred, no specific communications circuit additions are planned for European COB's. Because of the immense procedural and administrative problems inherent in NATO planning, USAF communications agencies in Europe are continually processing and updating paperwork necessary just to guarantee the wartime availability of the circuitry mentioned in the previous section. However, several general NATO communications improvement programs that could impact the level of communications support available for EDS purposes at a COB are being developed under an initiative titled NATO Integrated Communications System (NICS) . Since these programs represent possible improvements to the COB communications environment (as opposed to planned), they will be covered in the next section.

Possible COB C^3 Capabilities (Step 5).

The final step before beginning the evaluation process is to examine other technological possibilities for extending EDS to the COB level. Unlike the existing and planned sections which focused on potential piggybacking options, this portion of the study explores the use of new ADPE and communications systems and technologies that could be used in the EDS program.

ADPE. Beside using existing and/or programmed ADPE resources, the option to obtain additional equipment for exclusive use by the COB's is a viable alternative. Buying new resources to fill this requirement represents a straight add-on cost to the established EDS program. In this light, it would be necessary to minimize the cost of the additional equipment to make the option competitive. Three alternatives appear to be feasible choices given the technical and monetary requirements: purchase more of the same equipment under the EDS contract; procure standard micro terminals through the joint Air Force-Navy contract; or obtain ADPE as part of the Phase IV contract.

More EDS-Contract Terminals. Certainly, the option to buy more of the same equipment guarantees compatibility and ease of integration. Seventy-plus terminals would be required to equip each COB. This option will be referred to as "EDS" for analysis purposes.

Joint Air Force-Navy Contract. The Zenith Z-100 microcomputer has been chosen by the Air Force and Navy for joint procurement as the standard personal computer to be used by those services. Unless an Air Force agency can show a requirement for a specific capability not provided through the Z-100 contract, they will be required to procure the Zenith computer (62:). This option will be referred to as "Z-100" for analysis purposes.

Phase IV Contract. Several models of stand-alone micros are available through the Phase IV contract. The one that best fits EDS COB specifications is the Sperry UTS 60. The UTS 60 can be readily configured to interface with the new Standard Base Supply System computer, the Sperry 1160 (10:). Again, for analysis purposes, this option will be referred to as "Phase IV."

Communications. There are a myriad of communications systems available for consideration in extending EDS to the COB level. The following sections briefly outline the nature of these networks and their potential for helping the EDS program.

Defense Communications System. The DCS is a network of equipment, facilities, and people that provide the communications medium on which most US defense communications travel. It is composed of cable, broadband and narrowband radio, and satellite systems that extend around the world. The system is owned and operated by the Department of Defense. The DCS provides "backbone" communications by connecting major bases and nodes throughout Europe. DCS circuitry does not normally extend to the COB level.

NATO Integrated Communications System (NICS). NICS is a program designed to integrate Department of Defense DCS resources and networks with communications systems owned and operated by our European allies. Included in the latter are the NATO satellite system, the ACE HIGH microwave and tropo-scatter system, and associated public communications resources. NICS would combine the resources of the Defense Communications System with those of NATO, providing a greatly enhanced and compatible communications system (49:14). Unlike the DCS, allied communications circuitry extends to the COB level, since most COB's are simply allied airfields (39:31). If this circuitry could be integrated with the DCS, substantial cost savings would accrue, as pointed out in the evaluation sections.

<u>Defense Satellite Communications Systems (DSCS)</u>. With the launch of the first DSCS III satellite, the Air Force increased its capability to support small, remotely located users with reliable, survivable long-haul communications. The DSCS program is, as indicated, in its third phase whereby the present DSCS II satellites (4 operational and 4 orbiting spares) will be replaced upon failure with the new DSCS III equipment. Improvements in directional signal steering and electronic counter-countermeasures make the DSCS III a significant improvement over its predecessors. Two tactical earth terminals, the TSC-94 and TSC-100, operating in the Super High Frequency (SHF) range, will support small users such as an EDS COB element (28:24). In addition to a ground terminal, a user must also have permission to access the DSCS satellite. Permission is obtained through formal

acceptance of a validated need established in the satellite User Requirement Data Base (URDB). Indications are that a requirement for a full-time, 2400 bps duplex data circuit between the COB and a European MOB could be feasibly supported by the DSCS satellite in geosynchronous orbit above the Indian Ocean (7:). Channel requirements on the satellite in orbit above the Atlantic Ocean have saturated the capacity of that system although circuit redistribution between the two satellites is possible if deemed appropriate by system controllers (7:).

MILSTAR. The MILSTAR program seeks to challenge the frontiers of satellite communications technology. Unlike the DSCS program, MILSTAR is still in the conceptual and research and development phases, with initial operating capability expected to be achieved in the early 1990's if Congressional funding holds up. A combination of jam resistancy, nuclear hardening, and orbital crosslinks will make the planned seven MILSTAR satellites the most capable warfighting space segment ever. As many as 4000 earth terminals are expected to be built (61:46) at a minimum cost of $500K each (24:21). MILSTAR will operate in the Extremely High Frequency (EHF) range, although MILSTAR satellites will also carry UHF transponders for communication with older mobile users. No SHF, and therefore DSCS, compatibility is planned (61:46).

In addition to ground system procurement, an EDS COB-to-MOB logistics link would have to be validated in the URDB. Requirements for ground hardware and channel reservations on

MILSTAR satellites are being consolidated by the Deputy Commander for Strategic Systems, Electronic Systems Division, Air Force Systems Command, Hanscom AFB, MA (64:). Most likely, the EDS COB-MOB hardware funding would have to be provided by the using command (USAFE) in the overall Air Force buy (54:).

Leased Circuitry. As discussed in the earlier existing systems section, the COB communications concept called for a leased line connecting selected COB's with their Main Operating Base supply computers. It was noted that in reality, no substantive action has been taken to satisfy this requirement. The presence of this validated requirement in current war plans should ease the implementation process if an appropriate agency pushes for its activation.

Commercial Switched Data. One of the alternate modes of communication between EDS MOB locations is public data networks. In Central Europe, these commercial, "Western Union"-type systems are extensive and offer a great many unique and flexible data services. For EDS COB purposes, a contract for direct connectivity from an ADPE source to the network could be established. Since the sponsor MOB is already slated to have transmit/receive capability over this system, connectivity could be affected.

Two data services stand out as most applicable to the EDS COB problem. First, Datex-L is a circuit switching system operating anywhere from 50 to 9600 bps. Twenty-two semi-hardened electronic switches have been installed in 18 cities throughout Germany. For traffic volumes of less than 1000 minutes per month, this service is the least expensive.

The other system is Datex-P -- a packet switched network similar to MINET, operating at 2400 to 48,000 bps. Datex-P uses 17 semi-hardened switches that are collocated with their Datex-L counterparts. For traffic volumes between 1000 and 5000 minutes per month, this service is more cost effective (46:42).

Meteor Burst Communications (MBC). MBC has gained increasing attention as a viable form of long range communication. MBC makes use of ionized trails created by the daily destruction of millions of meteors reentering the earth's atmosphere to bounce VHF signals to a distant party. Communications are possible from one to 1200 miles.

A typical MBC setup would consist of a master station and a number of remote terminals. The master station sends a continuous probe on a given frequency. When a usable meteor trail is in the correct geometrical position, the probe is reflected in such a way that the distant terminal can receive it whereupon the distant terminal responds and a link is established. Each trail is typically usable for only a few hundred milliseconds, thus requiring a burst of data followed by a waiting period for the next usable trail. Calculations have shown that the average annual wait time is about 20 seconds resulting in an average yearly communications throughput of (effectively) 100 words per minute continuously (52:70). Stated another way, it has been shown that a one second duration message of 270 characters (1900 bits) could be sent to 50 remote terminals in less than eight minutes with a 99% probability of reception (8:). Obviously, such a system would only be feasible for systems incorporating relatively short messages where a few minutes delay would be acceptable. Anticipated EDS activity at COB's meet this constraint.

MBC is not strictly a theoretical concept. Several systems are in daily operational use including the SNOTEL system, which consists of more than 500 stations throughout the Western United States. Each transmits water resource data to two centrally located master stations. Similarly, the Alaskan MBC system provides much of the same kind of information to authorities in that state. Also, the U.S. Navy is extensively involved in several MBC test programs (13:50).

The meteor-reflected signal properties are interesting for military applications in several respects. First, the footprint is relatively small (15 by 30 miles on average (52:69)), allowing more effective use of scarce radio frequencies and greatly reducing the possibility of interception and jamming. Secondly, MBC will probably recover more quickly from the effects of a nuclear detonation than will conventional HF. Finally, there are no "skip zones" -- dead spots in signal coverage -- in MBC as compared to HF (52:72-73).

An important limitation concerning the use of MBC is its susceptibility to man-made noise. The more this noise is present, the less the ability to use the extremely weak received signal. Therefore, less information can be exchanged. Calculations have demonstrated that an increase in the noise level of 10 decibels over the background noise level will reduce communications throughput by one third (13:51). In the noisy environment of a military airfield, this could be a severe limiting factor. Conversely, most terminals in the SNOTEL and Alaskan systems are unattended and far from intensive civilized environments.

Costs for MBC equipment are quite reasonable. Master stations range from $40,000 to $100,000, while remote terminals are only $5 to $10,000 (52:72). All come with an RS-232 interface for compatibility with a wide variety of input/output equipment.

Joint Tactical Information Distribution System (JTIDS). JTIDS is a long-term, expensive program designed to provide the Air Force with a secure, nodeless, jam-resistant, distributed network of data and voice communications in a tactical environment. The primary thrust of the JTIDS program is concerned with air surveillance and defense although its potential for satisfying other tactical data requirements is obvious.

Basically, JTIDS is an advanced radio system which provides "information distribution, position location and identification capabilities" (47:11) to tactical elements participating in the JTIDS net. A large number of users, from individual fighter aircraft to major command and control centers, can be integrated into the net by a technique called Time Division Multiple Access (TDMA). Using the authorized 51 frequencies in the 960 to 1215 MHz range and TDMA, a total of 128 separate nets is possible. Each net is divided into timeslots which are, in turn, assigned to a user for transmission and reception.

The automatic radio relay function of JTIDS is particularly important for EDS purposes. Each JTIDS terminal can be set up to automatically rebroadcast messages received in a given timeslot. Thus, a ground terminal could transmit a message which would be picked up by, say, an orbiting AWACS or JTIDS-equipped fighter aircraft, and automatically relayed to a distant control center. Thus, characteristics of this frequency range which limited communications to line-of-sight can be extended up to 500 miles through JTIDS airborne relay (47:24).

Three types of terminals are planned: Class 1 terminals for large airborne and surface C2 systems, Class 2 terminals for smaller aircraft and C2 elements, and Class 3 units for manpack applications. NATO and U.S. E-3A's and certain elements of the Air Force Tactical Air Control System (radar units primarily) are receiving the Class 1 terminals. Class 2 units, which are scheduled for testing in 1985, are being developed for F-15 and F-16 aircraft as well as some Army applications . Class 3 terminals are conceptual only with no development plans pending (47:37). The Class 1 and 2 terminals will pass data at very fast rates (30 to 238 kilobits per second) and are priced accordingly -- $900,000 per Class 1 terminal; $180,000 for each Class 2 terminal (47:38).

As mentioned earlier, JTIDS applications have been restricted to air surveillance and defense needs. No plans exist for extending JTIDS capabilities to other functional areas. Similarly, no terminals are planned for the Wing/ Squadron Operations Center level. One must conclude that any attempt to incorporate EDS requirements into the JTIDS program now or in the near future would simply not be addressed. The potential for EDS use of such a system lies in the post-1990 timeframe.

Adaptive High Frequency (HF) Radio. Recent improvements in HF technology, coupled with acknowledgements of the access and survivability limitations of satellite communications, have resulted in a reevaluation of HF radio as a viable form of long-range communications in a wartime environment. Newer radios are capable of automatically scanning selected frequencies to pick out the most usable of those authorized. Other features include selective calling of users in a net, reducing the fatigue of listening to constant HF static noise. These newer radios are often used in conjunction with equipment such as the TRQ-35 Tactical Frequency Management System which analyzes spectrum conditions and provides information about the optimum and otherwise minimally acceptable frequencies for use between any two points.

Other innovations include the Advanced Narrowband Digital Voice Terminal (ANDVT) which combines encryption and modem capabilities into a small "blackbox", permitting transmission of either digitized voice or data information at speeds varying from 300 to 2400 bps. This device incorporates a background noise suppressor and coding techniques that "allow the terminal to operate with frequencies and channel conditions that would not normally be usable for digital transmissions." (26:8) Such a device could be hooked to the front end of an HF radio, communicating with similar equipment at the user destination.

Even with the improvements in the HF arena, limitations of this medium are apparent. HF frequencies are volatile, changing in quality from time period to time period, often to the degree of non-usability. The spectrum is crowded, making authorizations extremely limited in a wartime situation. HF is very susceptible to jamming, interference and interception because of its broadcast characteristics. Finally, the potential disruption in the ionosphere due to a nuclear detonation could drastically change the characteristics of HF performance.

Packet Switched Radio. The U.S. Army is currently developing and testing a packet switched radio system that would incorporate both packet switched technology and narrowband burst radio transmission to provide a high-speed, addressable, and survivable data distribution system (25:123). The test centers around the PRC-118 radio developed by Hazeltine Corporation. Operating in the 1.7 gigahertz range (high UHF), the PRC-118 represents a testbed upon which to evaluate packet switched radio technology. As such, the PRC-118, in its present configuration, is an experimental design only -- significant changes are expected if and when a packet radio system is fielded (48:).

Designed for employment in a tactical environment where geographical user dispersal is limited, the radio operates in a line-of-sight mode, restricted to less than 40 miles even under optimal conditions (flat terrain, high antenna placement, large power output (58:)). The Army has contracted for 1000 units in order to conduct tests and experiment with the technology.

Through its Rome Air Development Center, the Air Force is aware of the Army's efforts and the operation of packet radio test sites on the West Coast. However, no AF operational requirements have been submitted for such a system (51:).

It should be emphasized that the PRC-118 radio is an <u>experimental</u> system with no anticipated initial operational capability date nor stated DoD requirements for such a system. It is quite possible that this kind of system may never be fielded. Also, for EDS purposes, the limited range of these line-of-sight radios would require that EDS users be integrated into other (probably Army) networks within the area. For these reasons, packet switched radio technology is viewed as a long term possiblity for EDS communications, not a short term solution of interest here.

<u>Network of Networks</u>. Through the use of standard

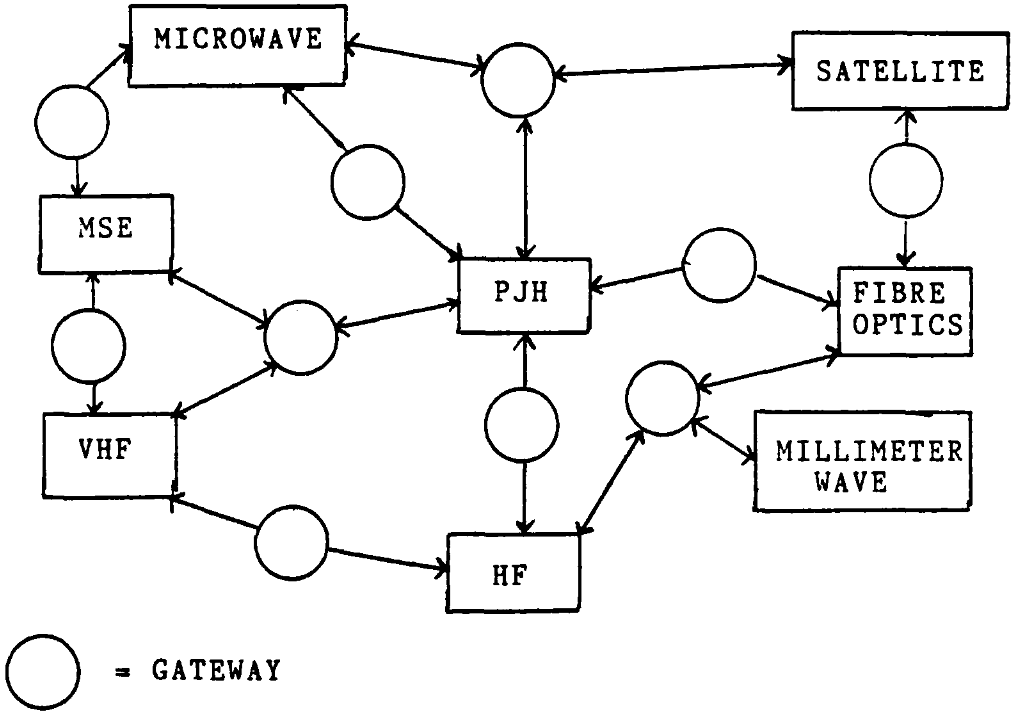


Fig 6. Network of Networks (43:28)

communications protocols such as the DoD Standard Transmission Control and Internet Protocols (TCP/IP) used in MINET, it is possible to connect unique C^3 networks, each using various transmission mediums, into a single integrated network where information is passed via packet switched technology to any user in the system. "Gateways" would connect subscribers with access to dissimilar communications mediums as depicted in Figure 6. Thus, a packet-switch radio net using say, the PRC-118, could enter MINET to exchange information with the many subscribers in that system. Theoretically then, the incorporation of standard communication protocols and gateway technology could "integrate, directly and automatically, all the communication resources available" (43:27) within a combat theater. However, while conceptually possible, such a configuration has many, many coordination hurdles to overcome before even the first elements can be fielded. Certainly this kind of integration of communication resources will not be available for EDS use in the near term.

MINET Extension. A very attractive alternative is to extend the MINET system of leased data circuits down to the COB level. Such an extension would permit each COB processor (given the correct communications protocol inclusions) access to the MINET network in the same way that the MOB EDS terminals are programmed. Thus, all EDS processors (MOB and COB) are tied into a single high speed, reliable data communications system, exchanging information through advanced packet switching technology.

However, conversations with the MINET program managers (57:) indicate that access to the MINET system by the COB's will be limited to dial-up capability only. Thus, instead of leasing MINET circuitry, the COB's must use common user (AUTOVON or commercial) communications to dial into the system. For EDS purposes, this means that the COB processors can access the MOB facilities via MINET, but not vice-versa. Such a capability is of limited use in automatically identifying and directing the shipment of the nearest critical spare source.

Technical Feasibility (Step 6)

Table 3 provides a summary of all candidate automatic data processing equipment (ADPE) and communications systems

TABLE 3

Summary of Candidate and Feasible Alternatives

EXISTING SYSTEMS		PLANNED SYSTEMS		POSSIBLE SYSTEMS	
COMM	ADPE	COMM	ADPE	COMM	ADPE
Commercial Circuitry*	None	None	CONSTANT CONTROL	DCS	EDS*
Air Force Circuitry*			WOMIS	NICS*	Z-100*
Radio			CSS*	DSCS*	Phase IV*
			DCAMS*	MILSTAR*	
			Phase IV	Leased Circuits*	
			TSC*	Commercial Circuits*	
			CLS*	MBC*	
				JTIDS	
				Adapt HF*	
				Packet Radio	
				Network of Networks	
				MINET Extension*	

* -- Technically Feasible

considered in the previous sections. Of all the ADPE systems considered, only CONSTANT CONTROL and WOMIS do not meet the technical requirements outlined on page 45, simply because these programs do not provide hardware hosts for EDS software. Rather, these projects are designed to integrate software found on other systems through Local Area Network technology. No provisions are made for user applications software to be resident within a CONSTANT CONTROL or WOMIS piece of hardware.

It would be a mistake to ultimately dismiss the efforts of the CONSTANT CONTROL and WOMIS projects as inconsequential to the EDS program. For instance, the strawman System Operational Concept called for a system that would "provide a standardized command and control automation system exportable to USAFE wings, squadrons, and support work centers on main operating bases, collocated operating bases, dispersed operating bases, and forward operating locations." (21:6) Thus, although the present operational concept for these systems is as described above, tests and evaluations may turn out a considerably different product in both content and purpose. Additionally, in the far term, EDS interfaces with their applications software and communications will most likely be handled through CONSTANT CONTROL/WOMIS Local Area Network architecture. For these reasons, it remains advisable for EDS program managers to maintain close liason with their counterparts in these programs.

Of the remaining ADPE alternatives, all were determined capable of conforming to the specifications of either Configuration 1 or 2 (described in previous sections), especially since the need for an SBSS spare parts back-up file (50 MB) is deleted. All have external communications capability and include large amounts of directly accessible on-line storage. For ADPE not procurred through the EDS C^3 contract, software conversion costs could be required in order to ensure EDS software can run on the various systems.

On the communications side, only existing COB radio systems, JTIDS, Defense Communications System, Packet-Switched radio, and the Network of Networks concept were excluded. Existing radio systems are considered totally unreliable for continuous high speed data transmission without non-existant UHF/VHF radio repeaters or significant HF enhancements as described in the Adaptive HF section. DCS was excluded since it fails to extend to COB's in the majority of cases. JTIDS, Packet Switched Radio, and the Network of Networks concept, while not available for EDS use today or in the near future, should receive updated evaluation as they move to operational use and system maturity.

Reference to commercial communications was found in both the existing and possible settings. For evaluation purposes, this alternative is identical and is treated as such in future discussions.

The MINET extension option, although not capable of satisfying the requirement for continuously available, two way communications between COB and MOB EDS processors, will be passed on for futher evaluation since it has the potential to satisfy part of the need at a relatively low cost. This alternative cannot stand by itself as a communications solution -- it will have to be used in conjunction with one of the other options.

As indicated, Table 3 also summarizes alternatives that have been judged "technically feasible" for further evaluation under the Brown-Gibson method. The next chapter begins the process of evaluating these alternatives.

IV. Results

Introduction

Now that feasible ADPE and communications alternatives have been established, Step 8 of this study's methodology algorithm can begin. Here each alternative is evaluated using the Brown-Gibson approach which combines objective and subjective factor analysis. The results of this chapter are preferred ADPE and communications solutions for extending EDS to the COB level.

Objective Factor Analysis

Tables 4 and 5 depict the calculations to derive ADPE and communications cost figures needed for steps B1 through B3 of the Brown-Gibson approach. (As detailed in the Appendix, these steps involve computing annual costs for each alternative and then summing their reciprocals. Step A of the Brown-Gibson approach was accomplished in the final section of the previous chapter). Only costs for EDS products and services <u>over and above</u> what is normally provided under each alternative setting are considered. For example, under the Combat Supply System (CSS) option, only the additional mass storage devices needed specifically for increased EDS requirements are included. CSS hardware and support costs are already borne by CSS program funding. Although it is recognized that some software conversion will most likely be required to run on non-EDS contracted machines, it is assumed here that such a conversion could most easily and quickly be accomplished within Air Force resources, requiring no additional costs for this service.

Table 6 provides the data for Brown-Gibson steps B4 and B5 (multiplying the cost of each alternative times the results of Step B3 and then taking the reciprocal). Column 3 (OF Rating) is the objective factor rating for each ADPE and communications alternative.

TABLE 4

ADPE Cost Figures

ADDITIONAL COSTS (Millions)

ALTERNATIVE	HARDWARE	SOFTWARE CONVERS	ANNUAL MAINT	TOTAL COST	RECIPROCAL 1/TC
CSS	.210 (1)	AF	0	.210	4.762
DCAMS	.210 (1)	AF	0	.210	4.762
TSC	.210 (1)	AF	0	.210	4.762
CLS	.210 (1)	AF	0	.210	4.762
EDS	5.600 (2)	0	.504 (5)	6.104	.164
Z-100	.532 (3)	AF	.504 (5)	1.036	.965
PHASE IV	1.050 (4)	AF	.504 (5)	1.554	.6435

NOTES: (1) - Additional 30 MB Winchester hard disk for EDS applications; one per each of 70 COB's. Average cost $3000 based on Computer World Buyer's Guide, Oct 83. Although under Configuration 2 (see page 47), the existing memory capacity of these systems is probably sufficient, the EDS SPO expressed the desire that each COB EDS system should be a mini-MOB processor, capable of executing all proposed EDS functions in the event of a host MOB failure. (12:)

(2) - Estimated costs of 70 (1 per COB) additional, stand-alone systems off EDS contract. Estimated cost of minimum capability processor exceeds $80K per system (53:).

(3) - Estimated costs of 70 (1 per COB) Z-100 systems to include 192 KB RAM, 40 MB on-line storage, printer, operating system(s), and modems. Taken from Government Employees Association cost quotations.

(4) - Estimated costs of 70 (1 per COB) Sperry UTS-60 stand-alone microprocessors. Includes 128 KB RAM, 60 MB on-line storage, printer, controllers and modems. Prices provided through Ref 10.

(5) - Estimated at $600 per unit (67:) per month. $600 x 12 months x 70 units x = $504K.

TABLE 5

Communications Systems Cost Figures

COSTS (In Millions)

ALTERNATIVE	PRORATED EQUIP	LEASED	ANNUAL COML	MX/MISC	TOTAL COST	RECIP 1/TC
COMMERCIAL	0	0	.155 (1)		.155	6.452
AF CIRC (2)	0	0	0	.005	.005	200
NICS (3)	0	0	0	.005	.005	200
DSCS	3.983 (4)	0	0		3.983	.251
MILSTAR	3.433 (5)	0	0		3.433	.291
LEASED	0	.655 (6)	0		.665	1.504
MBC	.131 (7)	0	0		.131	7.634
ADAPT HF	.172 (8)	0	0		.172	5.814
MINET EXT	0	0	0	.005	.005	200
						621.9

NOTES: (1) Each base will process about 724 EDS messages containing, on average, 213,657 characters per day (45:App II,8-9). 213,657 characters per day x 30 days/month x 8 bits per character divided by 2400 bits per second (half-duplex connection) = 21,365.7 seconds per month. Ref 46 found that Datex-L is the most economical service for this amount of monthly traffic (46:112). Costs per base = 200 Deutsch Mark (DM) basic monthly charge + 120 DM monthly remote control unit charge + 214 DM monthly traffic charge (using 1 pfennig per second average charge (46:35) = 514 DM per month per base. 514 DM x 12 months x 70 COB's = 431,760 DM per year. 431,760 DM divided by 2.78 dollars per DM = 155K dollars per year.

(2) This option provides the capability for Configuration 2 only (see page 48). The EDS SPO considers this a viable, but unpreferred configuration.

(3) The capability of this option to provide switched communications between all COB sites is unknown.

(4) 103 TSC-94 terminals (all MOB's and COB's) at \$580K each (3:). Costs pro-rated over 15 year useful life. Would provide true totally integrated communications system where all users capable of two-way, full-time communications.

(5) 103 terminals (all MOB's and COB's) at \$500K each. Costs pro-rated over 15 year useful life. As with DSCS, would provide true totally integrated communications system.

(6) Based on \$9500 per year per circuit. 70 total circuits configured in accordance with Configuration 2. \$9500 per year figure provided by Mr. Jim Holride, Telecommunications Service Office, Scott AFB, IL, and is based on average leased costs for a 2400 bps data circuit between Equropean Main Operating Bases and nearest AUTODIN switch (29:).

(7) Includes 19 master stations (average: \$70K each) located at primary MOB's and 84 remote terminals at secondary MOB's and COB's (average: \$7500 each). Costs pro-rated over 15 year useful life. Such a system would provide a combination of Configuration 1 and 2 where any MOB could address any COB, but inter-COB communication would be restricted.

(8) Costs cited are for 103 ANDVT's at an estimated \$25K each (42:). Quantity is one per EDS MOB (33) and COB (70). Costs pro-rated over 15 year useful life. ANDVT's are considered minimally essential for the HF data capability described on page 70. ANDVT's would be married with USAF-provided HF radios as descibed in the "existing" comm systems section.

TABLE 6

ADPE/Communications Objective Factor Ratings

ADPE Objective Factor Rating

Alternative	[(Total Alt Cost)x(Total Recip Cost)]$^{-1}$	= OF Rating
CSS	$[(.210)(20.8)]^{-1}$	= .2287
DCAMS	$[(.210)(20.8)]^{-1}$	= .2287
TSC	$[(.210)(20.8)]^{-1}$	= .2287
CLS	$[(.210)(20.8)]^{-1}$	= .2287
EDS	$[(6.104)(20.8)]^{-1}$	= .0079
Z-100	$[(1.036)(20.8)]^{-1}$	= .0464
PHASE IV	$[(1.554)(20.8)]^{-1}$	= .0309
		1.000

Communications Objective Factor Rating

COMMERCIAL	$[(.155)(621.9)]^{-1}$	= .010
AF CIRCUITRY	$[(.005)(621.9)]^{-1}$	= .322
NICS	$[(.005)(621.9)]^{-1}$	= .322
DSCS	$[(3.983)(621.9)]^{-1}$	= .0004
MILSTAR	$[(3.433)(621.9)]^{-1}$	= .0005
LEASED	$[(.665)(621.9)]^{-1}$	= .0025
MBC	$[(.131)(621.9)]^{-1}$	= .012
ADAPT HF	$[(.172)(621.9)]^{-1}$	= .009
MINET EXT	$[(.005)(621.9)]^{-1}$	= .322
		1.000

AD-A153 584 ALTERNATIVES FOR EXTENDING THE EUROPEAN DISTRIBUTION SYSTEM'S LOG C3I (CO..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. K F DONOVAN 2/2

UNCLASSIFIED DEC 84 AFIT/GLM/LSM/84D-1 F/G 17/2 NL

END

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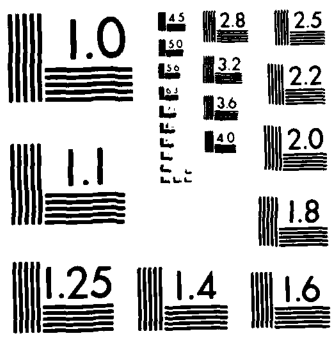

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Subjective Factor Analysis.

Tables 7 and 8 represent step C1 in the Brown-Gibson approach. Each subjective factor is given a weight through a pairwise comparison technique where each factor is compared to every other factor to determine a preference between the two (1 vs. 0) or indifference (1 assigned to each factor). As alluded to earlier, the lack of an experienced EDS user community required that the weighting of these subjective factors be limited to this study's author and managers in the EDS System Program Office (12:).

The set of subjective factors are not the same for both ADPE and communication alternatives analysis. Proximity and Political Feasibility were dropped from communication options consideration while Reliability was added. Rationale for this decision is as follows:

Proximity: In terms of communications connectivity, the actual location of the communications hardware is transparent to the EDS user since all communications options are directly connected to the EDS terminal.

Political Feasibility: Unlike some ADPE programs which are developed along very specific functional lines and often jealously guarded because of this fact, management of communications systems does not generally suffer from the same parochialism. Instead, communication systems managers, in their continuous efforts to satisfy a large and diverse operations community, are generally more focused on cost efficiency and performance effectiveness. Few in the communications management structure would complain if the same level of communications service could be placed on another communications system at a lower cost.

Reliability: Whereas no significant difference in the reliability of the alternative microcomputer systems was detected in this research, such is not the case for communications methods. From the evidence gathered, all the candidate microsystems were judged equally reliable, making the inclusion of this subjective factor unnecessary for ADPE analysis.

Tables 9 through 16 for ADPE alternatives, and 17 through 23 for communications options, represent step C2 of the Brown-Gibson model. Each ADPE and communications alternative is compared to one another within each appropriate subjective factor, again using the pairwise comparison technique. This analysis is the author's own, with notes provided for explanation and justification of general underlying rationale.

Tables 24 and 25 show the calculations necessary for step C3. Here the results of steps C1 and C2 are combined to give a Subjective Factor Measure for each alternative. The number after the equal sign for each alternative is the subjective factor measure for each ADPE and communications option.

TABLE 7

ADPE Subjective Factor Weighting

PAIRWISE COMPARISON	AVAIL	ACCESS	PROX	POLI FEAS	SURV	SUPP	SPACE REQ	FLEX
1	0	1						
2	1		0					
3	0			1				
4	1				0			
5	1					1		
6	1						1	
7	0							1
8		1	0					
9		0		1				
10		0			1			
11		1				1		
12		1					0	
13		0						1
14			0	1				
15			0		1			
16			0			1		
17			1				0	
18			0					1
19				1	0			
20				1		0		
21				1			0	
22				1				0
23					1	0		
24					1		0	
25					0			1
26						1	0	
27						0		1
28							0	1
SUM OF PREF:	4	4	1	7	4	4	1	6
TOTAL PREF: 31								
ALT RANK:	4/31	4/31	1/31	7/31	4/31	4/31	1/31	6/31
EQUALS:	.129	.129	.032	.226	.129	.129	.032	.194

TABLE 8

Communications Systems Subjective Factor Weighting

PAIRWISE COMPARISON	FACTOR AVAIL	ACCESS	RELI	SURV	SUPP	REQ	FLEX
1	0	1					
2	0		1				
3	1			0			
4	1				1		
5	1					1	
6	0						1
7		0	1				
8		0		1			
9		1			1		
10		1				0	
11		0					1
12			1	0			
13			1		0		
14			1			0	
15			1				0
16				1	0		
17				1		0	
18				0			1
19					1	0	
20					0		1
21						0	1
SUM OF PREF:	3	3	6	3	3	1	5
TOTAL PREF: 24							
ALT RANK:	3/24	3/24	6/24	3/24	3/24	1/24	5/24
EQUALS:	.125	.125	.250	.125	.125	.042	.208

TABLE 9

ADPE Subjective Factor Ranking - AVAILABILITY

PAIRWISE COMPARISON	CSS	DCAMS	TSC	CLS	EDS	Z-100	PHASE IV
1	1	0					
2	1		0				
3	1			0			
4	1				1		
5	1					0	
6	1						0
7		1	1				
8		0		1			
9		0			1		
10		0				1	
11		0					1
12			1	1			
13			1		1		
14			1			0	
15			1				0
16				1	1		
17				1		0	
18				1			0
19					1	0	
20					1		0
21						1	1
SUM OF PREF:	6	1	5	5	6	2	2
TOTAL PREF: 27							
ALT RANK:	6/27	1/27	5/27	5/27	6/27	2/27	2/27
EQUALS:	.222	.038	.185	.185	.222	.074	.074

TABLE 9 (CONT'D)

NOTES:

1. DCAMS not firmly funded.
2. Although TSC is available now, that availability is off-set by anticipated de-emphasis on incorporating EDS functions.
3. EDS option could implement software faster than non-dedicated machine -- assumes EDS contract let by September 84. Offsets advantages of having non-compatible machine available now.
4. DCAMS not funded; dedicated machines not funded. Implementing software on dedicated machine after funding (assuming both are funded at the same time) would be faster than on DCAMS.

TABLE 10

ADPE Subjective Factor Ranking - ACCESSABILITY

PAIRWISE COMPARISON	CSS	DCAMS	TSC	CLS	EDS	Z-100	PHASE IV
1	1	1					
2	1		0				
3	0			1			
4	0				1		
5	0					1	
6	0						1
7		1	0				
8		0		1			
9		0			1		
10		0				1	
11		0					1
12			0	1			
13			0		1		
14			0			1	
15			0				1
16				0	1		
17				0		1	
18				0			1
19					1	1	
20					1		1
21						1	1
SUM OF PREF:	2	2	0	3	6	6	6
TOTAL PREF: 25							
ALT RANK:	2/25	2/25	0/25	3/25	6/25	6/25	6/25
EQUALS:	.080	.080	.000	.120	.240	.240	.240

NOTES: 1. Dedicated machines will be more accessible.

TABLE 11

ADPE Subjective Factor Ranking - PROXIMITY

PAIRWISE COMPARISON	CSS	DCAMS	TSC	CLS	EDS	Z-100	PHASE IV
1	1	0					
2	1		0				
3	1			0			
4	1				1		
5	1					1	
6	1						1
7		1	0				
8		1		1			
9		0			1		
10		0				1	
11		0					1
12			0	1			
13			0		1		
14			0			1	
15			0				1
16				0	1		
17				0		1	
18				0			1
19					1	1	
20					1		1
21						1	1
SUM OF PREF:	6	2	0	2	6	6	6
TOTAL PREF: 28							
ALT RANK:	6/28	2/28	0/28	2/28	6/28	6/28	6/28
EQUALS:	.214	.072	.000	.072	.214	.214	.214

NOTES: 1. CSS, because of its supply orientation, will be closer to EDS user than any other non-dedicated machine. 2. Dedicated machines placed with EDS user.

TABLE 12

ADPE Subjective Factor Ranking - POLITICAL FEASIBLITY

PAIRWISE COMPARISON	CSS	DCAMS	TSC	CLS	EDS	Z-100	PHASE IV
1	1	0					
2	1		0				
3	1			0			
4	1				0		
5	1					0	
6	1						0
7		1	0				
8		1		1			
9		1			0		
10		1				0	
11		1					0
12			0	1			
13			0		1		
14			0			1	
15			0				1
16				1	0		
17				1		0	
18				1			0
19					1	0	
20					1		0
21						1	0
SUM OF PREF:	6	5	0	5	3	2	1
TOTAL PREF: 22							
ALT RANK:	6/22	5/22	0/22	5/22	3/22	2/22	1/22
EQUALS:	.274	.227	.000	.227	.136	.091	.045

TABLE 12 (CONT'D)

NOTES:

1. CSS, because of its inventory orientation judged more feasible than other non-dedicated machines.
2. Decision makers would most likely approve adaptation of logistics oriented systems for EDS purposes over procurement of dedicated machines from both monetary and proliferation of micros standpoints.
3. Procurement of dedicated machines could be implemented quicker than TSC because of TAC's resistance to non-operations use of their micros.
4. For EDS purposes, an "EDS" dedicated machine would be more attractive than a non-compatible Z-100 or Phase IV system.

TABLE 13

ADPE Subjective Factor Ranking - SURVIVABILITY

PAIRWISE COMPARISON	CSS	D AMS	TSC	CLS	EDS	Z-100	PHASE IV
1	1	1					
2	1		0				
3	1			1			
4	1				1		
5	1					1	
6	1						1
7		1	0				
8		1		1			
9		1			1		
10		1				1	
11		1					1
12			0	1			
13			0		1		
14			0			1	
15			0				1
16				1	1		
17				1		1	
18				1			1
19					1	1	
20					1		1
21						1	1
SUM OF PREF:	6	6	0	6	6	6	6
TOTAL PREF: 36							
ALT RANK:	6/36	6/36	0/36	6/36	6/36	6/36	6/36
EQUALS:	.167	.167	.000	.167	.167	.167	.167

NOTES: 1. TSC most likely located closer to primary targets (in the WOC which is close to runways). 2. All other machines have no inherent surv. advantages.

TABLE 14

ADPE Subjective Factor Ranking - SUPPORTABILITY

PAIRWISE COMPARISON	CSS	DCAMS	TSC	CLS	EDS	Z-100	PHASE IV
1	1	1					
2	1		0				
3	1			1			
4	1				0		
5	1					0	
6	1						0
7		1	0				
8		1		1			
9		1			0		
10		1				0	
11		1					0
12			0	1			
13			1		0		
14			1			0	
15			1				0
16				1	0		
17				1		0	
18				1			0
19					0	1	
20					1		1
21						1	0
SUM OF PREF:	6	6	3	6	1	2	1
TOTAL PREF: 25							
ALT RANK:	6/25	6/25	3/25	6/25	1/25	2/25	1/25
EQUALS:	.240	.240	.120	.240	.040	.080	.040

TABLE 14 (CONT'D)

NOTES:

1. TSC unit maintained. An in-theater repair capability will not be available to support a NATO scenerio for at least two years (71:).
2. Non-dedicated machines will have more maintenance support through larger community of interest.
3. Commonality of CLS Z-100 offset by anticipated support clauses in DCAMS/CSS contract.
4. Dedicated Z-100 will be easier to support because of its AF-wide standardization than either of the other two dedicated machines.

TABLE 15

ADPE Subjective Factor Ranking - SPACE REQUIREMENTS

PAIRWISE COMPARISON	CSS	DCAMS	TSC	CLS	EDS	Z-100	PHASE IV
1	1	1					
2	0		1				
3	1			1			
4	1				0		
5	1					0	
6	1						0
7		0	1				
8		1		1			
9		1			0		
10		1				0	
11		1					0
12			1	0			
13			1		0		
14			1			0	
15			1				0
16				1	0		
17				1		0	
18				1			0
19					1	1	
20					1		1
21						1	1
SUM OF PREF:	5	5	6	5	2	2	2
TOTAL PREF: 27							
ALT RANK:	5/27	5/27	6/27	5/27	2/27	2/27	2/27
EQUALS:	.185	.185	.223	.185	.074	.074	.074

NOTES: 1. Crememco slightly smaller than other standard micros. 2. Dedicated machines will require more space than if sharing other existing systems.

TABLE 16

ADPE Subjective Factor Ranking - FLEXIBILITY

PAIRWISE COMPARISON	CSS	DCAMS	TSC	CLS	EDS	Z-100	PHASE IV
1	1	0					
2	1		0				
3	1			0			
4	0				1		
5	0					1	
6	0						1
7		1	0				
8		1		1			
9		0			1		
10		0				1	
11		0					1
12			0	1			
13			0		1		
14			0			1	
15			0				1
16				0	1		
17				0		1	
18				0			1
19					1	0	
20					1		0
21						1	1
SUM OF PREF:	3	2	0	2	6	5	5
TOTAL PREF: 23							
ALT RANK:	3/23	2/23	0/23	2/23	6/23	5/23	5/23
EQUALS:	.130	.087	.000	.087	.262	.217	.217

TABLE 16 (CONT'D)

NOTES:

1. CSS, because of its inventory orientation, more willing to meet changing EDS requirements than other non-dedicated machines.
2. Dedicated machines will handle changes more readily than systems with non-EDS users on it.
3. Logistics-oriented systems more flexible to EDS requirements than TSC which is ops oriented.
4. "EDS" dedicated machines will more readily adopt software and system changes than other dedicated machines because of its commonality with MOB systems.

TABLE 17

Comm Subjective Factor Ranking - AVAILABILITY

PAIRWISE COMPARISON	COMMERCIAL	AF CIRC	NICS	DSCS	MIL	LEA	MBC	ADAPT HF	MINET EXT
1	1	1							
2	1		0						
3	1			0					
4	1				0				
5	1					1			
6	1						0		
7	1							1	
8	0								1
9		1	0						
10		1		1					
11		1			0				
12		0				1			
13		1					1		
14		1						1	
15		0							1
16			1	1					
17			1		1				
18			0			1			
19			1				1		
20			1					1	
21			0						1
22				1	0				
23				0		1			
24				1			0		
25				1				1	
26				0					1
27					0	1			
28					0		1		
29					0			1	
30					0				1
31						1	0		
32						1		1	
33						0			1
34							0	1	
35							0		1
36								0	1
SUM OF PREF:	7	6	4	5	1	7	3	7	8
TOTAL PREF: 48									
ALT RANK:	7/48	6/48	4/48	5/48	1/48	7/48	3/48	7/48	8/48
EQUALS:	.146	.125	.083	.104	.021	.146	.063	.146	.166

TABLE 17 (CONT'D)

NOTES:

1. Commercial hook-ups, although constrained by political factors, could be implemented relatively more quickly than satellite solutions (circuit requirement validation, hardware procurement) or NICS processes.

2. An engineering change might be required to configure COB-MOB lines for EDS data processing, substantially slowing implementation.

3. Purchasing additional communications hardware for EDS purposes presents political and system procurement obstacles to implementation.

4. Given significant funding pressure, availability of dedicated leased lines for quasi-EDS purposes might be substantially improved.

5. MINET extension dial-up capability can be implemented almost immediately.

6. MILSTAR viewed as available to EDS in the 1995 timeframe.

TABLE 18

Comm Subjective Factor Ranking - ACCESSABILITY

PAIRWISE COMPARISON	COMMERCIAL	AF CIRC	NICS	DSCS	MIL	LEA	MBC	ADAPT HF	MINET EXT
1	1	0							
2	0		1						
3	0			1					
4	0				1				
5	0					1			
6	0						1		
7	0							1	
8	1								1
9		0	1						
10		0		1					
11		0			1				
12		0				1			
13		0					1		
14		0						1	
15		1							1
16			1	1					
17			1		1				
18			1			1			
19			1				1		
20			1					1	
21			1						0
22				1	1				
23				1		1			
24				1			1		
25				1				1	
26				1					0
27					1	1			
28					1		1		
29					1			1	
30					1				0
31						1	1		
32						1		1	
33						1			0
34							1	1	
35							1		0
36								1	0
SUM OF PREF:	2	1	8	8	8	8	8	8	2
TOTAL PREF: 53									
ALT RANK:	2/53	1/53	8/53	8/53	8/53	8/53	8/53	8/53	2/53
EQUALS:	.038	.018	.151	.151	.151	.151	.151	.151	.038

TABLE 18 (CONT'D)

NOTES: 1. Dedicated EDS circuitry will be more accessible than shared resources.

2. Satellite circuits are assumed to be available on a full-time basis.

TABLE 19

Comm Subjective Factor Ranking - RELIABILITY

PAIRWISE COMPARISON	COMMERCIAL	AF CIRC	NICS	DSCS	MIL	LEA	MBC	ADAPT HF	MINET EXT
1	1	0							
2	1		0						
3	1			1					
4	1				1				
5	0					1			
6	1						1		
7	1							0	
8	1								1
9		1	0						
10		1		1					
11		1			1				
12		0				1			
13		1					0		
14		1						0	
15		1							1
16			0	1					
17			0		1				
18			0			1			
19			1				1		
20			1					1	
21			0						1
22				1	1				
23				1		1			
24				1			0		
25				1				0	
26				1					1
27					1	1			
28					1		0		
29					1			0	
30					1				1
31						1	0		
32						1		0	
33						1			0
34							1	1	
35							0		1
36								0	1
SUM OF PREF:	7	5	2	8	8	8	3	2	7
TOTAL PREF: 51									
ALT RANK:	7/51	6/51	2/51	8/51	8/51	8/51	3/51	2/51	7/51
EQUALS:	.137	.118	.039	.157	.157	.157	.059	.039	.137

TABLE 19 (CONT'D)

NOTES:

1. Point-to-point dedicated circuit more reliable than switched circuitry.

2. Present interoperability problems restrict NICS' reliability.

3. Reliability of HF considered relatively poor due to limited frequencies and propagation problems.

4. As an example of satellite system reliability, the link reliability of the Defense Satellite Communications System was above 98% during 1983 (70:).

TABLE 20

Comm Subjective Factor Ranking - SURVIVABILITY

PAIRWISE COMPARISON	COMMERCIAL	AF CIRC	NICS	DSCS	MIL	LEA	MBC	ADAPT HF	MINET EXT
1	1	0							
2	1		0						
3	1			1					
4	1				1				
5	1					1			
6	1						0		
7	1							0	
8	1								1
9		1	0						
10		1		1					
11		0			1				
12		1				1			
13		1					0		
14		1						0	
15		1							1
16			0	1					
17			0		1				
18			0			1			
19			0				1		
20			1					1	
21			0						1
22				0	1				
23				1		1			
24				1			1		
25				1				0	
26				1					1
27					1	0			
28					1		0		
29					1			0	
30					1				1
31						1	1		
32						1		0	
33						1			1
34							1	0	
35							0		1
36								0	1
SUM OF PREF:	8	6	1	7	8	7	4	1	8
TOTAL PREF: 50									
ALT RANK:	8/50	6/50	1/50	7/50	8/50	7/50	4/50	1/50	8/50
EQUALS:	.160	.120	.020	.140	.160	.140	.080	.020	.160

TABLE 20 (CONT'D)

NOTES:

1. Redundancy of circuitry and hardened switches provide a relatively high degree of survivability vis-a-vis other communications systems.

2. Satellite systems generally more survivable than unhardened terrestial systems.

3. Most AF circuitry between COB's and MOB's is leased from PTT's.

4. NICS not highly survivable because of above ground, nodal configuration.

5. HF susceptible to jamming; MBC is not.

TABLE 21

Comm Subjective Factor Ranking - SUPPORTABILITY

PAIRWISE COMPARISON	COMMERCIAL	AF CIRC	NICS	DSCS	MIL	LEA	MBC	ADAPT HF	MINET EXT
1	0	1							
2	0		1						
3	0			1					
4	0				1				
5	1					1			
6	1						0		
7	1							1	
8	1								1
9		1	0						
10		1		0					
11		1			0				
12		1				0			
13		1					0		
14		1						0	
15		1							0
16			0	1					
17			0		1				
18			0			1			
19			1				0		
20			1					1	
21			0						1
22				1	0				
23				1		1			
24				1			0		
25				1				1	
26				0					1
27					0	1			
28					1		1		
29					0			1	
30					0				1
31						1	0		
32						1		1	
33						0			1
34							0	1	
35							0		1
36								0	1
SUM OF PREF:	4	8	3	6	3	6	1	6	7
TOTAL PREF: 44									
ALT RANK:	4/44	8/44	3/44	6/44	3/44	6/44	1/44	6/44	7/44
EQUALS:	.091	.183	.068	.136	.068	.136	.023	.136	.159

TABLE 21 (CONT'D)

NOTES:

1. Military circuitry more easily maintained in wartime than a foreign countries' commercial system used for USAF purposes.

2. Uniqueness of MBC is a disadvantage to supportability. Spare parts and maintenance expertise would be difficult to obtain for such an uncommon system.

3. Present interoperability problems of NICS restricts its supportability.

4. Simplicity of maintaining dial-up capability provides advantages to MINET extension option.

TABLE 22

Comm Subjective Factor Ranking - SPACE REQUIREMENTS

PAIRWISE COMPARISON	COMMERCIAL	AF CIRC	NICS	DSCS	MIL	LEA	MBC	ADAPT HF	MINET EXT
1	1	1							
2	1		1						
3	1			0					
4	1				0				
5	1					1			
6	1						0		
7	1							0	
8	1								1
9		1	1						
10		1		0					
11		1			0				
12		1				1			
13		1					0		
14		1						0	
15		1							1
16			1	0					
17			1		0				
18			1			1			
19			1				0		
20			1					0	
21			1						1
22				0	1				
23				0		1			
24				0			1		
25				0				1	
26				0					1
27					0	1			
28					1		1		
29					1			1	
30					0				1
31						1	0		
32						1		0	
33						1			1
34							1	1	
35							0		1
36								0	1
SUM OF PREF:	8	8	8	0	3	8	3	3	8
TOTAL PREF: 49									
ALT RANK:	8/49	8/49	8/49	0/49	3/49	8/49	3/49	3/49	8/49
EQUALS:	.163	.163	.163	.000	.061	.163	.062	.062	.163

TABLE 22 (CONT'D)

NOTES:

1. Interfacing landlines requires very little space.

2. Satellite, HF and MBC communications all require significant additional hardware.

3. DSCS uses minimum of 8 foot dishes along with associated radio equipment. MILSTAR's EHF dishes considerabley smaller.

4. MBC equipment is small and portable.

TABLE 23

Comm Subjective Factor Ranking - FLEXIBILITY

PAIRWISE COMPARISON	COMMERCIAL	AF CIRC	NICS	DSCS	MIL	LEA	MBC	ADAPT HF	MINET EXT
1	1	0							
2	1		0						
3	1			1					
4	1				1				
5	1					0			
6	1						0		
7	1							1	
8	1								0
9		1	0						
10		0		1					
11		0			1				
12		0				1			
13		1					0		
14		0						1	
15		1							0
16			0	1					
17			0		1				
18			0			1			
19			1				1		
20			0					1	
21			1						0
22				1	1				
23				1		0			
24				1			0		
25				1				1	
26				1					0
27					1	0			
28					1		0		
29					1			0	
30					1				0
31						0	1		
32						0		1	
33						1			0
34							0	1	
35							1		0
36								1	0
SUM OF PREF:	8	3	2	8	8	3	3	7	0
TOTAL PREF: 42									
ALT RANK:	8/42	3/42	2/42	8/42	8/42	3/42	3/42	7/42	0/42
EQUALS:	.190	.071	.050	.190	.190	.071	.071	.167	.000

TABLE 23 (CONT'D)

NOTES:

1. AF Circuitry somewhat static in its configuration due to need to service many different types of COB users.

2. Present interoperability problems of NICS restricts its flexibility.

3. MINET extension fixed in one-way dial-up configuration.

4. Satellite communications more open to new subscribers/operating modes than point-to-point circuitry.

TABLE 24

ADPE Subjective Factor Weight x Rating

ALTERN					
	AVAIL SFWxSFR +	ACCESS SFWxSFR +	PROX SFWxSFR +	POL FEA SFWxSFR +	
	SURV SFWxSFR +	SUPPOR SFWxSFR +	SPACE SFWxSFR +	FLEX SFWxSFR =	
CSS	(.129)(.222) +	(.129)(.080) +	(.032)(.214) +	(.226)(.274) +	
	(.129)(.167) +	(.129)(.240) +	(.032)(.185) +	(.194)(.130) =	.191
DCAMS	(.129)(.038) +	(.129)(.080) +	(.032)(.072) +	(.226)(.227) +	
	(.129)(.167) +	(.129)(.240) +	(.032)(.185) +	(.194)(.087) =	.144
TSC	(.129)(.185) +	(.129)(.000) +	(.032)(.000) +	(.226)(.000) +	
	(.129)(.000) +	(.129)(.120) +	(.032)(.223) +	(.194)(.000) =	.046
CLS	(.129)(.185) +	(.129)(.120) +	(.032)(.072) +	(.226)(.227) +	
	(.129)(.160) +	(.129)(.240) +	(.032)(.185) +	(.194)(.087) =	.168
EDS	(.129)(.222) +	(.129)(.240) +	(.032)(.214) +	(.226)(.136) +	
	(.129)(.167) +	(.129)(.040) +	(.032)(.074) +	(.194)(.262) =	.177
Z-100	(.129)(.074) +	(.129)(.240) +	(.032)(.214) +	(.226)(.091) +	
	(.129)(.166) +	(.129)(.080) +	(.032)(.074) +	(.194)(.217) =	.144
PHASE IV	(.129)(.074) +	(.129)(.240) +	(.032)(.214) +	(.226)(.045) +	
	(.129)(.166) +	(.129)(.040) +	(.032)(.074) +	(.194)(.217) =	.128

TABLE 25

Comm Subjective Factor Weight x Rating

ALTERNATIVE	AVAIL SFWxSFR SUPPOR SFWxSFR		ACCESS SFWxSFR SPACE SFWxSFR		RELIA SFWxSFR FLEX SFWxSFR		SURV SFWxSFR	
		+		+		+		
		+		+		=		
COMMERCIAL	(.125) (.146) (.125) (.091)	+ +	(.125) (.038) (.042) (.163)	+ +	(.250) (.137) (.208) (.190)	+ =	(.125) (.160) .134991	+
AF CIRCUITRY	(.125) (.125) (.125) (.183)	+ +	(.125) (.018) (.042) (.163)	+ +	(.250) (.118) (.208) (.071)	+ =	(.125) (.120) .106864	+
NICS	(.125) (.083) (.125) (.068)	+ +	(.125) (.151) (.042) (.163)	+ +	(.250) (.039) (.208) (.050)	+ =	(.125) (.020) .067246	+
DSCS	(.125) (.104) (.125) (.136)	+ +	(.125) (.151) (.042) (.000)	+ +	(.250) (.157) (.208) (.190)	+ =	(.125) (.140) .145145	+
MILSTAR	(.125) (.021) (.125) (.068)	+ +	(.125) (.151) (.042) (.061)	+ +	(.250) (.157) (.208) (.190)	+ =	(.125) (.160) .131332	+
LEASED	(.125) (.146) (.125) (.136)	+ +	(.125) (.151) (.042) (.163)	+ +	(.250) (.157) (.208) (.071)	+ =	(.125) (.140) .132489	+
MBC	(.125) (.063) (.125) (.023)	+ +	(.125) (.151) (.042) (.062)	+ +	(.250) (.059) (.208) (.071)	+ =	(.125) (.080) .071747	+
ADAPT HF	(.125) (.146) (.125) (.136)	+ +	(.125) (.151) (.042) (.062)	+ +	(.250) (.039) (.208) (.167)	+ =	(.125) (.020) .103715	+
MINET EXT	(.125) (.166) (.125) (.159)	+ +	(.125) (.038) (.042) (.163)	+ +	(.250) (.137) (.208) (.000)	+ =	(.125) (.160) .106471	+

Alternative Preference Measure (APM) Determination

Step D of the Brown-Gibson approach involves assigning weights to objective vs. subjective factors. Intuitively, one might be inclined to pick objective factors as more important than subjective considerations when choosing among Defense-related program alternatives. However, the EDS SPO felt in this case the opposite was true (12:). The rationale centered on the relatively small amounts of money involved (less than $20 million for the entire EDS C3 segment) as opposed to the technical, political, and procedural problems associated with making the system work. Thus, the Program managers believe, and this author concurs, that the objective (cost) factors should be weighted 30% (.30) and the subjective factors 70% (.70). Although this weighting serves as the guiding criteria, other objective-subjective weighting combinations are also examined.

Table 26 represents steps E and F of the Brown-Gibson methodology. The weights assigned in step D above are multiplied by previously calculated objective and subjective factor measures for each alternative. The result is provided in Column 4 as the Alternative Preference Measure for each ADPE and communications system option. Each alternative is presented in descending order of attractiveness -- the best alternative (highest APM) on top, the worst choice (lowest APM) on bottom.

TABLE 26

ADPE/Communications Alternative Preference Measure (APM)

	ADPE APM					Col 4
Alternative	OF (Weight)	x OF (Measure)	+	SF (Weight)	x SF (Measure)	= APM
CSS	(.3)	(.2287)	+	(.7)	(.191)	= .20231
CLS	(.3)	(.2287)	+	(.7)	(.168)	= .18621
DCAMS	(.3)	(.2287)	+	(.7)	(.144)	= .16941
EDS	(.3)	(.0079)	+	(.7)	(.177)	= .12627
Z-100	(.3)	(.0464)	+	(.7)	(.144)	= .11472
TSC	(.3)	(.2287)	+	(.7)	(.046)	= .10081
PHASE IV	(.3)	(.0309)	+	(.7)	(.128)	= .09887
	Communications APM					
AF CIRCUITRY	(.3)	(.322)	+	(.7)	(.107)	= .1715
MINET EXT	(.3)	(.322)	+	(.7)	(.106)	= .1708
NICS	(.3)	(.322)	+	(.7)	(.067)	= .1435
DSCS	(.3)	(.0004)	+	(.7)	(.145)	= .1016
COMMERCIAL	(.3)	(.010)	+	(.7)	(.135)	= .0975
LEASED	(.3)	(.0025)	+	(.7)	(.132)	= .0932
MILSTAR	(.3)	(.0005)	+	(.7)	(.131)	= .0919
ADAPT HF	(.3)	(.009)	+	(.7)	(.104)	= .0755
MBC	(.3)	(.012)	+	(.7)	(.072)	= .0540

V. Analysis

The previous chapter provided rank-ordered ADPE and communications alternatives that were derived using subjective weighting and to some extent, variable cost data. The purpose of this chapter is to conduct sensitivity analysis on the most critical of these factors to determine the range in which the results of the previous chapter remain valid.

Before beginning this analysis, it should be pointed out that among the automated data processing equipment considered, the piggyback option is clearly a superior choice to procuring new systems and that the Combat Supply System is the best specific alternative. The emergence of CSS as the preferred choice among these options parallels the EDS System Program Office's predilection towards this particular alternative as specified in their System Operational Concept paper.

Because CSS ranked first in both objective and subjective factor ratings, no possible change in the relative weights of objective vs. subjective factors (k vs. k-1) could cause any other alternative to move ahead of CSS. Similarly, the Combat Logistics System always ranks second until objective factors are weighted at less than 5% (subjective factors greater than 95%), at which point the procurement of more EDS terminals for the COB's becomes the second best choice.

Only when the total costs (Column 5 of Table 4) of CSS exceeds that of other piggybacking options by about $80K does a different system (CLS) supplant the Combat Supply System as the preferred choice.

Matters are not so clear cut on the communications side. A number of mitigating factors could influence the results. First, recognizing that miscellaneous costs is a rather open-ended category, an analysis was performed on the effects that increases in these areas would have on the rankings.

Adding maintenance costs for options that call for purchasing new equipment (DSCS, MILSTAR, MBC, Adaptive HF) certainly would only decrease their relative ranking. Of these four systems, the highest ranking attained is only fourth (DSCS). On the other hand, if miscellaneous costs for the three best options (AF Circuitry, NICS, and MINET extension) is increased to $70K each (or about $1,000 per COB per year), the four best choices remain as in Table 26. Not until these *miscellaneous* costs exceed $100K for each of the AF circuitry, NICS, and MINET extension alternatives, does a change in the preferred option (commercial circuitry) take place. Given the nature and description of these systems, such a large annual recurring cost for these options seems quite unlikely. Additionally, any relative advantage gained by a lower ranked alternative as a result of miscellaneous cost increases would undoubtably be offset by similar increases in maintenance costs associated with (but not originally included in) lower ranking options. Only the commercial communications alternative would gain from such increases.

As pointed out earlier, communications managers are often highly cost-oriented. If k (weight of objective, or cost, factors) is progressively increased at the expense of subjective factors, the relative advantages of the first three choices continue to increase. At a 50-50 cut, no real changes occur in the relative ranking while at a 70-30 split, commercial communications moves slightly ahead of DSCS into fourth place.

One other possibility cannot afford to be overlooked. If, at some point, the Air Force provided satellite terminals at all MOB's and COB's for other than EDS purposes and assuming they could be configured for shared EDS use, costs for the two satellite options (DSCS and MILSTAR) would be reduced to miscellaneous costs, greatly changing the relative rankings. Under such a scenario, both satellite alternatives move ahead of all others, with the remaining options retaining their relative original order.

This sensitivity analysis addresses only major change possibilities, ignoring the innumerable minor perturbations that could be examined. Even with these assumption adjustments considered, the overall results of the previous chapter remain valid.

VI. Conclusions and Recommendations

The primary objective of this research was to determine the best alternative(s) for extending the European Distribution System's command, control, communications, and intelligence subsystem to the Collocated Operating Base level. As an adjunct to this objective, it was also necessary to determine whether such an extension was warranted. These two objectives were pursued using seven research questions as guidelines. Research Questions 1 and 2 examined the worth of extending the system to the COB level, Research Questions 3 through 6 aimed at finding technically feasible alternatives for making that extension, and Research Question 7 dealt with producing the best choice from among those alternatives through the use of the Brown-Gibson evaluation technique. Although close technical coordination was established with the EDS System Program Office, evaluation of alternatives was accomplished independently.

Conclusions.

The Brown-Gibson model used in this study proved itself as a flexible decision-making aid, useful in applications far beyond the facility location problem most commonly associated with it. Certainly while the rankings of alternatives should not be considered as absolutes (particularly in the case of communications options), general preferences can be discerned for further detailed consideration. Additionally, weights assigned to the evaluation criteria in this model were derived without the benefit of inputs from users experienced on the EDS system. In evaluating a C^3 system using subjective factors, it is highly desirable to obtain as much user feedback as possible in order for the system to evolve properly. This leads to the first recommendation which is presented in the next section.

This study demonstrated that if EDS is to become an effective theater-wide logistics management tool, inclusion of COB resources is mandatory since well over half of the theater's critical spares will be located at these bases. Thus, extension of the EDS C^3I system is critical to the effectiveness of the wartime European Distribution System.

Regarding specifics for making this extension, research showed that from an automated data processing standpoint, the piggybacking option (integrating EDS requirements with other developing systems) is clearly superior to procuring new computer equipment. On the communications side, although one choice emerged as better than the others, it is not necessary, in fact it is unadvisable, to restrict selection of a communications medium to a single system. EDS planners have recognized this and programmed four different modes of communication into their MOB-based systems. Similarly, the EDS COB extension should include multiple communication paths. Specific computer and communication systems are recommended below. The recommendations in the communications area are general in nature. Much detailed research into such problems as what specific circuitry exists where (in the case of

NICS), what engineering or procedural changes would be required for interswitchboard data transfer (as in the AF circuitry option), or the availability of commercial data service outside Central Europe (Greece and Turkey for example) is necessary before these general conclusions can be effectively implemented.

This study found that although major wartime communication plans call for activation of dedicated logistics computer circuits in the event of hostilities, little if any action necessary to activate these circuits has been taken. Costs associated with providing this service were therefore additive in this model -- had they not been, the results would have been quite different. An update on where European communications planners stand on this issue is required.

It became obvious during the course of this research that the logistics community is very active in their efforts to exploit rapidly expanding microprocessing technology. Projects to develop deployable microcomputers are underway in most of the primary logistics fields including distribution, maintenance, supply, and mobility. However, these initiatives are taking place independent of each other. This may prove detrimental for at least two reasons. First, the intended employment environment (the Wing Operations Center area) cannot support the multiplicity of systems planned for these larger bases unless functional areas are combined through local area network technology. Secondly, the costs associated with developing and fielding multiple logistics systems that potentially could be combined into one may not be justified. A recommendation concerning this problem is presented below.

Recommendations.

One. Once the initial EDS C^3I system has been operational for an acceptable time, operators of the system should be queried for their assessment of the weights used in this study in order to substantiate the results of this research.

Two. Integrating EDS requirements with existing Combat Supply System (CSS) microsystems is recommended. The advantages to the EDS user in subjective factors combine with the relatively low cost of this alternative to provide a clear choice among many possible alternatives.

Three. EDS system managers should examine a combination of Air Force circuitry, MINET dial-up procedures, NATO integrated communications circuits, commercial communications and satellite options for inclusion in the COB-based systems. Obviously, an analysis of costs and corresponding benefits for a system with multiple communication links would have to be performed.

Four. Lest the leased circuit option be dismissed too quickly, recommend EDS program managers pursue an update on where European communications agencies stand on their stated plans to provide leased circuits to the COB's for logistics purposes.

Five. More integration and coordination among logistics

ADP program managers is recommended in order to reduce the proliferation of equipment and promote C^3 efficiency in the intended operational environment.

As a final note, more so than other defense related areas, command, control and communications system acquisition is marked by its necessarily evolutionary nature. The C^3 portion of EDS will probably prove no different. The MOB-based EDS system provides the "core" (68:84) in this evolutionary acquisition process, hopefully to be improved upon by developing, testing, and refining the necessary communications and ADPE recommended here for the Colocated Operating Base level.

Appendix A: Mathematical Description of the Brown-Gibson Algorithm

A) Eliminate any alternative that does not meet certain basic requirements. (This was done in the technical feasibility check.)

B) Compute an objective-factor measure of performance OF_i for each alternative:

1) Compute total annual cost C_i for each alternative.

2) Determine the reciprocal $1/C_i$ for each alternative.

3) Sum the reciprocals: $\sum (1/C_i)$

4) Multiply the cost C_i for each alternative times the sum of the reciprocals: $C_i \sum (1/C_i)$

5) The objective factor OF_i equals the reciprocal of step 4.

C) Determine key subjective factors and estimate their subjective factor measure SF_i for each alternative:

1) Determine a factor rating w_j for each subjective factor by using a forced-choice, pairwise comparison procedure. Each subjective factor is compared against all others, one at a time, and a preference between them is determined (value 1) or they are rated equal (value 0). The result is a quantified importance rating for each factor.

2) Rank all alternative R_{ij} within each subjective factor, again using a forced-choice, pairwise comparison procedure. Each alternative is compared against all others for a particular subjective factor and a preference is made.

The result is a ranking for each alternative within a subjective area.

3) The subjective factor measure SF_i for each alternative is determined by multiplying the alternative's ranking for each subjective factor R_{ij} times its corresponding weight w_j and summing the results.

D) Assign the weights k and 1-k to be used for the objective and subjective factors respectively. For instance, if objective factors are all important and subjective factors are to be ignored, k = 1 and 1-k = 0.

E) Determine an alternative preference measure APM_i for each alternative using the formula:

$$APM_i = k\,(OF_i) + (1-k)\,(SF_i) \qquad 0<k<1$$

F) Select the alternative with the maximum APM.

Appendix B: Glossary of Acronyms

AB	AIR BASE
ADPE	AUTOMATED DATA PROCESSING EQUIPMENT
AFCC	AIR FORCE COMMUNICATIONS COMMAND
AFLC	AIR FORCE LOGISTICS COMMAND
AFSC	AIR FORCE SYSTEMS COMMAND
ALC	AIR LOGISTICS CENTER
ANDVT	ADVANCED NARROWBAND DIGITAL VOICE TERINAL
APM	ALTERNATIVE PREFERENCE MEASURE
ARPANET	ADVANCED RESEARCH PROJECTS AGENCY NETWORK
BLSS	BASE LEVEL SELF-SUFFICIENCY SPARES
BPS	BITS PER SECOND
C3	COMMAND, CONTROL, AND COMMUNICATIONS
C3I	COMMAND, CONTROL, COMMUNICATIONS AND INTELLIGENCE
CLS	COMBAT LOGISTICS SYSTEM
COB	COLLOCATED OPERATING BASE
CONUS	CONTINENTAL UNITED STATES
CSS	COMBAT SUPPLY SYSTEM
DCA	DEFENSE COMMUNICATIONS AGENCY
DCAMS	DEPLOYABLE CORE AUTOMATED MAINTENANCE SYSTEM
DCS	DEFENSE COMMUNICATIONS SYSTEM
DDN	DEFENSE DATA NETWORK
DLA	DEFENSE LOGISTICS AGENCY
DMES	DEPLOYABLE MOBILITY EXECUTION SYSTEM
DSCS	DEFENSE SATELLITE COMMUNICATIONS SYSTEM
ECD	EUROPEAN COMMUNICATIONS DIVISION

EDS	EUROPEAN DISTRIBUTION SYSTEM
EDSA	EUROPEAN DISTRIBUTION SYSTEM AIRCRAFT
EHF	EXTREMELY HIGH FREQUENCY
ESD	ELECTRONICS SYSTEMS DIVISION
FOL	FORWARD OPERATING LOCATION
FOSK	FOLLOW-ON SPARES KITS
GSA	GOVERNMENT SERVICES AGENCY
HF	HIGH FREQUENCY
JTIDS	JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM
KB	KILOBYTES
LAN	LOCAL AREA NETWORK
LOG-C3I	LOGISTICS COMMAND,CONTROL, COMMUNICATIONS AND INTEL
LRC	LOGISTICS READINESS CENTER
MB	MEGABYTES
MBC	METEOR BURST COMMUNICATIONS
MHZ	MEGAHERTZ
MICAP	MISSION INCAPABLE - PARTS
MMICS	MAINTENANCE MGT AND INFORMATION CONTROL SYSTEM
MOB	MAIN OPERATING BASE
NATO	NORTH ATLANTIC TREATY ORGANIZATION
NICS	NATO INTEGRATED COMMUNICATIONS SYSTEM
OF	OBJECTIVE FACTORS
PACAF	PACIFIC AIR FORCES
PDN	PUBLIC DATA NETWORK
PEWS	PORTABLE EDS WORKSTATION SYSTEM
POS	PEACETIME OPERATING STOCKS
PSN	PUBLIC SWITCHED NETWORK

PTT	PUBLIC TELEPHONE AND TELEGRAPH
SAC	STRATEGIC AIR COMMAND
SBSS	STANDARD BASE SUPPLY SYSTEM
SF	SUBJECTIVE FACTORS
SHF	SUPER HIGH FREQUENCY
SNUD	STOCK NUMBER USER DIRECTORY
SPO	SYSTEM PROGRAM OFFICE
TAC	TACTICAL AIR COMMAND
TAFIG	TACTICAL AIR FORCES INTEROPERABILITY GROUP
TCC	TRANSPORTATION CONTROL CELL
TCP/IP	TRANSMISSION CONTROL AND INTERNET PROTOCOL
TDMA	TIME DIVISION MULTIPLE ACCESS
TFW	TACTICAL FIGHTER WING
TSC	TAF SMALL COMPUTER
UHF	ULTRA HIGH FREQUENCY
URDB	USER REQUIREMENTS DATA BASE
USAFE	UNITED STATES AIR FORCES IN EUROPE
VHF	VERY HIGH FREQUENCY
WOC	WING OPERATIONS CENTER
WRM	WAR READINESS MATERIAL
WRSK	WAR READINESS SPARES KITS

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Title: ALTERNATIVES FOR EXTENDING THE EUROPEAN DISTRIBUTION SYSTEM'S LCG C3I SUBSYSTEM TO THE COLLOCATED OPERATING BASE LEVEL

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This study analyzed the communications and Automated Data Processing Equipment (ADPE) options available to extend the original configuration of the new European Distribution System's (EDS) Command, Control, Communications, and Intelligence (C^3I) subsystem from Europe's Main Operating Base (MOB) level to the Collocated Operating Base (COB) level. This extension is essential in order to achieve the payoffs predicted by RAND Corporation Study Number R-2860-AF upon which EDS development was justified.

The basic approach taken to conduct this analysis was to first determine acceptable configurations for the extended system. With these in mind, C^3 systems that are fielded or soon to be implemented in the European theater were examined for possible integration into EDS. Additionally, emerging and other possible C^3 technologies were identified for further analysis. These preceding steps provided a list of C^3 alternatives for evaluation under a technique known as the Brown-Gibson approach which rank-orders the options using both subjective and objective (cost) criteria.

The results of this analysis indicated that the ADPE segment of the COB EDS system should be integrated with other ADPE systems destined for use at the COB and that the Combat Supply System, currently under development at the Air Force Data Systems Design Center, was the preferred choice. From a communications standpoint, analysis showed that several alternatives should be incorporated including existing Air Force and North Atlantic Treaty Organization (NATO) circuitry, dial-up entry into the Movement Information Network (MINET), and perhaps satellite solutions. Sensitivity analysis demonstrated that these results were valid over a wide range of cost considerations and evaluation treatments.